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AN AUTOMATIC COMPUTERIZED ULTRASONIC CLEANLINESS RATING SYSTEM AND CALIBRATION STANDARDS

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The developmental work and associate studies were performed under the technical supervision of Messrs. J. Halgren, General Supervisor, R. Cellitti, Chief Research Metallurgist and J. Abar, Research Engineer. Others who cooperated in the research efforts were Messrs. C. Carter, E. Plofsky, A. Filinovitz and L. DiSilvestro.

Comments are solicited on the application of information contained in the report. Suggestions concerning further developmental studies are cordially invited.

ABSTRACT

This project relates to the design and assembly of a computerized ultrasonic quality control system for assessing the internal cleanliness of steel billets. The individual units which comprise the complete system are described and discussed in detail with regard to their function, limitations and operational procedure.

Nonmetallic inclusion severity as assessed by AMS 2301 procedure showed no correlation with ultrasonic inclusion severity determined with the automatic computerized cleanliness rating system.

Nonmetallic inclusion ratings as determined by a modified magnetic particle technique and the subject system were compared for various cleanliness levels and found to display a similar order of inclusion severity. A positive trend rather than exact correlation was observed and is primarily due to limited inspection coverage inherent with magnetic particle inspection procedure.

Various inclusion sizes as assessed by light microscopy were closely related to ultrasonic inclusion category as measured by the computerized quality control system.

Additional activities are recommended in areas directly related to the subject project.

Glossary of Abbreviations
For Computer Maintenance Tests

AC	Accumulator
CLA	Clear accumulator
ION	Interrupt on
KCC	Clear accumulator and keyboard flag
KSF	Skip if keyboard flag is 1
MA	Memory address
MB	Memory buffer
PC	Program counter
SNA	Skip if accumulator is not zero
SWI	Switch register key No. 1
TLS	Clear teleprinter flag and print and/or punch the character
TSF	Skip if teleprinter flag is 1

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SECTION I

INTRODUCTION

1.1 General Description and Problem

The metallurgical properties of engineering alloys are adversely influenced by nonmetallic inclusions which must be quantitatively assessed for meaningful engineering design leading to reliable performance of critical components. The assessment of materials for nonmetallic inclusions is presently provided by microscopic, macroscopic and magnetic particle inspection procedures which are time consuming, destructive and severely limited in inspection coverage. In addition, these inspectional methods are subject to personal interpretive opinions which vary significantly between different operators.

It has been recognized that ultrasonic inspection of semifinished material confers the most advantageous and economical approach for assessing internal cleanliness. The advantages are clearly evident by the nondestructive nature of the test coupled with rapidity and reproducibility. The economics of the technique are apparent in that nearly complete inspection coverage is obtained thereby qualifying the material prior to performing costly manufacturing operations. Past ultrasonic methods for assessing internal cleanliness were confined to laboratory models that required manual treatment of the data. Difficulties were encountered in the analysis and control of the prodigious amount of data which can be accrued in a relatively short time.

The primary goal of this effort was to design and assemble an automatic cleanliness rating system which embodied ultrasonic principles for the detection of nonmetallic inclusions and incorporated high speed data processing facilities. Further, the project was concerned with developing ultrasonic cleanliness standards and relating these standards with magnetic particle cleanliness ratings in accord with Aerospace Materials Specification AMS 2301.

1.2 Project Phases and Objectives

The initial phase of the project entailed design and assembly of an automatic cleanliness rating system that embodied ultrasonic facilities for detecting nonmetallic inclusions along with high speed data processing instrumentation for rapid interpretation, analysis and reporting. The instrumentation is described in various sections of this report.

1. Ultrasonic station (inclusion detection) - Section 6
2. Computer station (mathematical & analysis treatment) - Section 7
3. Teletype station (data report) - Section 8

The second phase was to determine the relationship, if any, between Aerospace Materials Specifications 2301 and the developed system with respect to severity rating of nonmetallic inclusions. The relationship is discussed in Section 10.

The third phase involved the correlation of inclusion severity as assessed with the developed system and subsequently measured by metallographic techniques for the purpose of translating ultrasonic inclusion information into conventional terms and understandable concepts.

The final phase of the project was to develop and submit ultrasonic calibration standards which represented various levels of inclusion severity for permanent reference bars.

1.3 Project Authorization

The work conducted under this project was sponsored by Army Materials Research Agency, Watertown, Massachusetts, and Rock Island Arsenal, Rock Island, Illinois, under Contract No. DA-19-066-AMC-314(X) and OI-066-D6-01366(X), Project No. 15036. Technical supervision and project coordination was under the guidance of Mr. N. H. Fahey, Army Materials Research Agency.

SECTION 2

SUMMARY

During the first phase of the project, several approaches were considered for modification of the ultrasonic main frame to obtain the desired gating flexibility. Final considerations and designs led to a single channel system which featured a multiple switching module to select any one of these preset conditions for gate start, gate length and sensitivity. A special purpose hybrid computer was electronically matched with the ultrasonic unit through an interface network which inverted and compressed the ultrasonic signal for acceptance by the computer. The interface network provides a specific time delay for synchronization of the pulse signal. Release of ultrasonic signals to the computer are regulated by a set of switches mounted to the inspection tank which (1) instruct the computer to sample, classify and count various levels of signal magnitudes and (2) mathematically process the data and report a cleanliness rating.

Phase II consisted of ultrasonically examining material for inclusion severity with the system developed in Phase I and conducting step down magnetic particle inclusion ratings by AMS 2301 method.

Parallel steps of billet height (H), 4/5 H, 3/5 H, 2/5 H and 1/5 H were examined by magnetic particle procedure. The ultrasonic cleanliness results corresponding to these levels did not show a correlative relationship. Subsequent tests utilizing a modified magnetic particle inspection in which a greater number of steps were examined did indicate a positive correlative relationship.

In Phase III, certain inclusion sizes were ultrasonically located, removed from billets and examined metallographically. Metallographic location of inclusions was affected by grinding, polishing and examining approximately one hundred layers for each inclusion category.

Four ultrasonic cleanliness standards were established in the final phase. Ultrasonic cleanliness ratings were derived by treating the number of various inclusion sizes with weighting factors. Ultrasonic ratings ranged from 0.9 with consumable electrode vacuum arc remelt to 108.6 for open hearth.

SECTION 3

CONCLUSIONS

Phase I - An ultrasonic cleanliness rating system incorporating high speed data processing facilities was successfully designed, assembled and tested. The system is automatic and can rapidly assess internal cleanliness of semi-finished materials with a high degree of resolution. With a scanning rate of 30 ft/min, the system can resolve inclusions of 0.008 in length. The width of inspection field for 100% return of inclusion signal is approximately 0.050 inch. The scanning pattern provides a grid of 0.008 inch x 0.050 inch for x-y direction. The dimensional limits for the vertical direction is controlled through an adjustable ultrasonic gate which recognizes and locks on the largest inclusion size in the gate. The system compiles, classifies and statistically evaluates nonmetallic inclusion content. A report format is automatically printed to show the count of various size inclusions, distribution and mathematical treatment with a weighted factor. Provisions are made to increase the resolving power of the system by amplification of the defect or inclusion magnitude in coarse multiples. Utilizing a 3x amplification, inclusion areas of 6×10^{-6} in^2 are detectable.

Phase II - Aerospace Materials Specification 2301 severity ratings of various cleanliness grades did not correlate with ultrasonic severity ratings. In both instances, identical weighting factors were utilized to derive severity ratings. The relation between ultrasonic severity and magnetic particle severity improves upon increasing the number of magnetic particle inspection levels. Since a considerable number of magnetic particle inspection levels are required for reliable appraisal, the economics associated with production quality control operations become prohibitive. More extensive magnetic particle tests on the laboratory level are required to obtain lineal conversion factors for equating ratings of severe cleanliness grades. It is not intended to criticize magnetic particle per se, but rather to point out the inadequacy of rating procedures such as AMS 2301 and limitations in measurement of small size inclusions.

Phase III - A high degree of correlation was established between ultrasonic inclusion category (size) and actual areas as measured by light microscopy. Four separate inclusion categories (1, 3, 9 and 15) were located in a 5 in. x 5 in. billet cross section and removed for metallographic examination. Inclusion areas were determined for each category by measuring the largest inclusion concentration contained in a metallographic field of 0.16 inch diameter. This field was experimentally determined and corresponds to the maximum area of ultrasonic response for the transducer and water path employed. Inclusion severity expressed in ultrasonic terms (category) is convertible to actual inclusion area for more meaningful information.

Phase IV - Ultrasonic cleanliness calibration standards were developed for four discrete cleanliness levels. The purpose of the standards are to verify the operational accuracy of the transducer, ultrasonic system and stability of instrumentation. The standards vary in severity ratings from very clean material (0.9) to very "dirty" material of 108. For comparative values, ultrasonic severity ratings of 5 and 15 correspond to AMS 2301 severity ratings of .03 and .45, respectively. The order of cleanliness ranking for the standards

agree with cleanliness ranking generally encountered for the steelmaking practice. The cleanest standard was prepared from consumable electrode vacuum arc remelt material (0.9). The next in order were electric furnace vacuum degassed (5.4), open hearth (46.6) and open hearth vacuum degassed (108.6).

SECTION 4

RECOMMENDATIONS

As a result of the findings and consideration of critical areas associated with optimum utilization of the developed system, the following recommendations are presented:

1. Develop ultrasonic inspection procedures that cross-refer and supplant present inspectional procedures expressed by ASTM, SAE, AMS, etc.

   (a) conduct extensive magnetic particle tests to obtain a complete spectrum including limits of magnetic particles - ultrasonic correlation and conversion factors for an extended range of material cleanliness.

   (b) conduct additional ultrasonic - metallographic correlation studies.

   (c) determine applicability and reproducibility of various transducer designs on certain materials and microstructures.

   (d) provide inspection technique, equipment standardization and calibration standards.

2. Develop acceptance standards that are related to mechanical properties which effect gun barrel and bearing quality applications. Mechanical parameters of particular interest are fatigue, fracture toughness, and evaluating the ratio of stress intensity for crack opening to that of critical stress intensity at onset of unstable plane-strain fracturing.

3. Develop acceptance standards for aircraft quality material at various strength levels.

4. Develop a production method for complete ultrasonic inspection of all mill products for critical applications.

SECTION 5

PRELIMINARY DISCUSSION

The conventional method of measuring internal defects or non-metallic inclusions by ultrasonic technique consists of visually interpreting the amplitude of a video trace which represents a certain quantity of reflected energy. Since the amplitude of the trace is related to defect area, the magnitude of the defect can be determined upon establishment of comparative standards such as a synthetic defect in the form of a flat bottom hole. For more precise measurement, the defect can be located and examined by painstaking metallographic preparations which were conducted in this study.

The amplitude of the trace as displayed on the cathode ray tube also corresponds to a certain D.C. voltage, which in this study was monitored with special electronic instrumentation designed to sample the ultrasonic voltage at select intervals, perform a continuous count of various size inclusions and mathematically process the counts to obtain a cleanliness rating.

To accurately ascertain the defect area ultrasonically, the depth location of the defect and the focusing length of the transducer must be considered. With two inclusions of identical area, a greater amount of sound energy is absorbed or scattered in transit to the inclusion that is more distant from the transducer thereby influencing the magnitude of the trace. The focal length of the transducer also influences the attenuation or diminishing effect of the sound energy. The sound energy is more concentrated as the focal point approaches the defect. In both instances, attenuation losses are correctible by adjustment of sensitivity control. For this reason, it is important to separate the billet depth into multiple areas and inspect each multiple or "gated" area with a corrected sensitivity setting. The ultrasonic instrumentation was designed accordingly.

SECTION 6

ULTRASONIC STATION

6.1 Main Frame

The ultrasonic instrumentation was specially designed to provide a three gated system in which separate and individual controls for gate start, gate length and sensitivity were incorporated in a single chassis type UM 721 reflectoscope. Gate selection is controlled by a three position switch which displays video signal amplitudes pertinent to the selected gate. In this manner, various inspection layers corresponding to select billet depths can be preset for gate location with a corrected sensitivity setting and continuously scanned without further adjustments. The gate starts are adjustable from 0.030 to 24.0 inches (pulse echo delay through steel) and the gate lengths from 0.030 to 12 inches. However, a gate length of 3/8 inch is the minimum practical limit which may be set due to certain instability of gate voltage below this dimension.

Three separate decibel attenuation controls are mounted in the pulser-receiver section. Each control is adjustable from 0 to 60 decibels in increments of one decibel.

The main horizontal sweep circuitry was modified to provide a fixed pulse repetition rate of 750 cycles per second for any sweep setting. That is, 1/750 second is the time interval between pulses that actuate the transducer. The video trace which represents the defect area is linearly related to the D.C. output voltage between 0.2 and 2.0 inches of vertical signal amplitude on the cathode ray tube. For a 2 inch amplitude signal, the conditioned output level is approximately-10 volts. This level is adjustable through vernier dial potentiometers discussed in a later section. Detailed operating instructions and procedures are furnished in Section 15.1.

6.2 Analog Interface

A separate module was designed and constructed to condition the ultrasonic output signal (0 to 12 volts) with the input requirements of an analog to digital converter (0 to -10 volts). In addition to conditioning the signal, a synchronization pulse is incorporated in the module to instruct the analog to digital converter when to sample the analog signal. Specific attention was given to timing of the analog to digital converter to ensure that the sampling phase did not coincide with a falling or rising edge of the analog signal (Figure 1). The synchronization pulse train that activates the analog to digital converter is triggered from an internal timing circuit contained in the ultrasonic main frame.

The analog to digital converter samples and classifies the ultrasonic signal into one of the sixteen categories or inclusion sizes depending upon the voltage level. The voltage range (0 to -10 volts) is divided into sixteen equally spaced categories as follows:

Category	D.C. Volts Range Corresponding to Category (negative values)
1	0 to 0.62
2	0.63 to 1.25
3	1.26 to 1.87
4	1.88 to 2.50
5	2.51 to 3.12
6	3.13 to 3.75
7	3.76 to 4.37
8	4.38 to 5.00
9	5.01 to 5.62
10	5.63 to 6.25
11	6.26 to 6.87
12	6.88 to 7.50
13	7.51 to 8.12
14	8.13 to 8.75
15	8.76 to 9.37
16	9.38 to 10.00

A separate D.C. voltage source and digital voltmeter is housed in the analog interface module to ascertain whether the analog to digital converter is performing accurately by introducing a known D.C. voltage level and noting the teletype print out response.

Provisions are also contained in this module for amplifying the ultrasonic signal in select multiples (1/2, 1, 2 and 3) to adequately resolve various material cleanliness grades. In instances where gross size defects are encountered, voltages in excess of -10 volts will occur necessitating less sensitivity and selection of a reduced amplification setting.

Offset and fine sensitivity vernier controls are provided as a means to adjust the high and low ends of the voltage range to correspond with a fixed signal amplitude. That is, a certain signal amplitude from a reference standard can be inserted in one of the upper categories (10 through 16) while maintaining a fixed voltage level in category 1.

6.3 Digital Interface Module

A second interface module that is associated with the computer is also fixtured in the ultrasonic station cabinet. This module contains an occupancy contact switch, busy indicator, alarm indicator and program interrupt facility. The occupancy contact switch regulates the release of ultrasonic signals to the analog to digital converter and generation of a typed report. While the occupancy contact switch is closed during a billet scan, the computer assimilates the data from the analog to digital converter. At the termination of the scan, the occupancy contact switch is opened thereby instructing the computer to mathematically process the data, type out a report and reset the counters of the memory unit to zero. The busy indicator (lamp) is lit from the instant the occupancy contact switch closes until the completion of a typed report. During this interval, the computer is operating and additional data will not be assimilated. A visual and audible alarm is also included in this module to signify whether the calculated cleanliness index of the scan

exceeded an allowable cleanliness limit which is arbitrarily selected and stored in computer memory.

Unlike the busy lamp which is automatically cancelled by the computer at the termination of a report, the alarm control must be manually reset. While ultrasonic data is being classified and stored in computer, the main program is interrupted and a sub-program introduced via the program interrupt facility. Complete operation procedures and instrument settings are, as previously stated, described in Section 15.1. The ultrasonic station is pictorially shown in Figure 2.

SECTION 7

COMPUTER STATION

7.1 Main Frame

The computer main frame is a high speed digital data processor that performs binary operations on 12 bit two's complement words and can retain 4096 words in magnetic core memory. Principal internal registers which store, extract, control and perform arithmetic operations consist of (1) program counter - determine the core memory address from which the next command of a stored program is to be extracted. (2) Memory address - location in memory core that is selected for insertion or retrieval of information. (3) Memory buffer - temporary location for all instructions that occur between processor and core memory, and (4) accumulator - performs the programmed mathematical operations and acts as a data input-output device. Each of these registers is visually displayed on the computer console panel with indicating lights which furnish information regarding the octal contents of the register. Figure 3 shows a block diagram indicating the flow of information between major registers.

A bank of switches are located at bottom of the console panel for manually entering binary machine language and command instructions. Six switches located to the extreme left are nonfunctional (Data and Inst. Field) and are to be disregarded. The twelve toggle keys associated with the switch register serve to introduce information (12 bit words) to the computer for assimilation into memory core. The switch register is divided into four segments each of which contains three switches for producing an octal digit number (0 to 7). In the up position, the left key in each segment of three keys represents 2^2 or 4. The center key represents 2^1 or 2 and the right key represents 2^0 or 1. In the down position, all keys are equivalent to zero.

A group of eight command switches are located to the right of the switch register and are used for the execution of certain instructions such as load address, start, examine, stop, continue, etc. The two switches to the extreme right (single step and single instruction) are only used for special diagnostic tests and should remain off (down position) during programming and data print out. The arrangement and identification of these switches are illustrated in Figure 4.

Directly above the command switches a series of mnemonic symbols are located to indicate the current state of computer activity. Briefly, these symbols denote the following operations:

SYMBOL	OPERATION
AND	Bit by bit multiplication
TAD	Two's complement add
ISZ	Increment and skip if zero
DCA	Deposit and clear accumulator
JMS	Jump to subroutine (remember location started from)
JMP	Jump - do not return
IOT	Input/output transfer instructions
OPR	Operate - sample contents of accumulator and link
Fetch	Extract information from core memory and place in memory buffer

SYMBOL	OPERATION
Execute	Entered for all memory reference instructions except jump
Defer	Indirect addressing
Break	Sequence of instructions is interrupted to allow transfer of information between core memory and external devices
ION	Interrupt on - (must be lit during billet analysis)
Run	Program is not blocked or suspended in a loop

7.2 Entering Programs

The initial or read in mode must be manually entered by way of the switch register and command keys located on the console panel. Seventeen octal addresses and address contents are required to load the read in mode program (RIM). The second program (binary loader - BIN) is entered by coded tape via the teletype reader. The third program (billet analysis) is coded on punched tape which is also automatically loaded via the teletype reader.

Approximately one half hour is required to program the computer. Once these programs are stored in memory, the computer is programmed indefinitely unless the computer memory cells are accidently or intentionally altered.

7.3 Modes of Operation

After the computer is programmed, the operator has the option of selecting one of seven operating modes. In addition to the billet analysis mode, provisions were made to include three calibration modes, two up date modes and a short report mode which are obtained by selecting the appropriate switch register key.

7.3.1 Billet Analysis Mode

This is the primary and only mode of operation in which a complete report detailing mathematical treatment and print out of a calculated cleanliness index is generated. The report format contains a heading which lists pertinent identification captions such as heat no., operator, gate no., etc., which are filled in by the operator.

After the heading is printed out, category, number of counts, percent of counts (frequency), progression factor and product are printed out with corresponding values. The stored index and calculated index are printed out at the bottom of the format. An illustration of the actual billet analysis format is shown in Figure 5. After the starting address is entered (see Section 15.3)the billet analysis mode is selected by placing all (twelve) keys of the switch register in the down position.

7.3.2 Calibrate 0 Mode

This calibrate mode is used as a direct check on the analog to digital converter. By introducing a certain D.C. voltage level to the input of the A/D converter and placing key No. 1 (left most key of switch register) in the up position, the category number corresponding to the voltage level is printed out. A print out (Figure 6) of the category will continue to occur every second until switch register key No. 1 is placed in the down position. Notice should be made that closure of the occupancy contact switch is not required.

7.3.3 Calibrate 1 Mode

The calibrate 1 mode is similar to the calibrate 0 mode with the exception that an analog signal is introduced to the input of the analog to digital converter which requires closing of the occupancy contact switch. Upon opening the occupancy contact switch, calibrate 1 format is printed out with a heading which is filled in by the operator. All categories are printed out with counts occurring in those categories experiencing the applicable voltage level. Figure 7 illustrates the format that is obtained. Calibrate 1 mode is obtained by lifting key No. 5 in the switch register.

7.3.4 Calibrate 2 Mode

This mode is principally used in conjunction with the ultrasonic standard reference block. With the transducer properly aligned over a 1/64 inch diameter hole in the standard block, the gain setting is adjusted to obtain the required signal amplitude. By lifting key No. 4 in the switch register and closing the occupancy contact switch momentarily, calibrate 2 mode is printed out. A copy of this mode is shown in Figure 8.

7.3.5 Stored Index Update Mode

When the billet analysis report format is generated, an empirical stored index value is printed out. The stored index is arbitrarily chosen as a threshold of cleanliness acceptability and may be altered at any time the computer is not busy. The stored index is updated by lifting key No. 2 in the switch register and entering the desired numerical value via the teletype keyboard.

7.3.6 Progression Factor Selection Mode

Four sets of progression factors may reside in computer memory at a given time. The set of progression factors desired is obtained by using a certain combination of the two right most keys (11 and 12) in the switch register while operating in the billet analysis mode. The pattern for selecting a given set is as follows:

KEY 11	KEY 12	PROGRESSION FACTOR SET
Down	Down	1
Down	Up	2
Up	Down	3
Up	Up	4

Figure 9 indicates the series of numerics associated with each progression factor set.

7.3.7 Short Form Mode

This mode produces an abbreviated format in which the identifying heading is omitted and only three columns of data are printed out, namely category, count and frequency (percent of count).

The cleanliness index is also omitted. The brevity of this format provides a rapid tabulation of data for cursory inspections or check on count magnitude for various categories. Where the billet analysis print out requires approximately $2\frac{1}{2}$ minutes, the short form is completed in one minute. This mode is entered by lifting key No. 6 on the switch register and activating the occupancy contact switches (during a billet scan). Figure 10 shows the format obtained in this mode of operation. Detailed instructions are presented in Section 15.3.

7.4 Program Changeover

As previously mentioned, only four sets of progression factors may occupy memory locations in the computer at one time. However, additional sets may be prepared on paper tape via the teletype unit and automatically transferred into computer memory replacing one or all four of the previous sets. Special changeover tapes are provided to accomplish the insertion of updated progression factors. Special instructions are typed upon lifting key No. 3 of the switch register. Detailed instructions are listed in Section 15.5.

SECTION 8

TELETYPE STATION

8.1 Reader Unit

Apart from the switch registers on the computer console and occupancy contact closures which introduce ultrasonic signals, communication with the computer takes place through the teletype station. Information or instructions entering the computer are conveyed by the reader unit which relays binary machine language contained on punched paper tapes. Two tape formats are utilized; Rim format and Bin format. Both formats contain sprocket holes, leader-trailer holes and a sequence of perforations and blanks which represent binary 1 and binary 0, respectively. To represent a single 12 bit word, two rows of perforation are required. The first row represents the left portion of the address and the second row represents the right portion of the address. The third row indicates the left part of the contents, and the fourth row indicates the right part of the contents. The Rim format tape (Figure 11) is organized such that address A - Contents A, Address B - Contents B, etc., are sequenced. In most programs, however, the addresses are stored in a consecutive manner and it is only necessary to enter a series of contents after the starting address of the block is loaded. Tapes displaying an address followed by a consecutive series of contents are Bin format tapes (Figure 12).

To enter instructions contained on paper tapes, the designated tape is placed in the reader unit and the appropriate starting address manually set in the switch register. The required command keys on the computer console and the telereader start switch are utilized to start and advance the tape through the reader. At the completion of the tape, the sprocket drive will automatically stop. Complete operating instructions are detailed in Section 15.2.

8.2 Tape Puncher

From time to time it will be necessary to reproduce additional program tapes due to tape wear from repeated use. This is easily accomplished via the punch unit located on the teletype frame. For tape reproduction, the teletype mode switch must be in the local position. The tape to be reproduced is placed in the reader unit. A duplicate tape is generated by pressing the punch "On" button and energizing the reader start switch. Detailed procedures are shown in Section 15.2.

Figure 13 shows a photograph of the teletype reader, punch and keyboard.

SECTION 9

INSPECTION ANALYSIS

9.1 Data Acquisition

As previously mentioned, the occupancy contact switch controls the release of ultrasonic signals to the analog to digital converter. A pair of occupancy contact switches attached to the side of the immersion tank with magnetic holders are used for this purpose. An arm was mounted on the traversing bridge to activate these switches. When the first contact switch is closed at the start of a scan, ultrasonic signals are converted to digital equivalents acceptable to the central processor of the computer. The analog to digital converter is synchronized with the ultrasonic pulser to examine the ultrasonic voltage level every 1/750 of a second and classify the level into one of sixteen categories. Each category occupies a certain location in the computer's memory bank and counts occurring for all categories are continuously stored and summed as the transducer scans the billet. At the termination of the scan, the arm trips a second switch thereby opening the occupancy circuit instructing the computer to perform a mathematical analysis of the acquired counts. (Note that the occupancy light remains lit for the duration of calculation and print out).

The computer determines the total number of counts for all categories, calculates the percent count for each category and with the use of stored weighting factors computes an ultrasonic cleanliness rating.

9.2 Report of Data

All data and mathematical treatment for each scan is typed and the billet analysis format is obtained. In the first column of the format, the categories of 1 through 16 are listed. The second column indicates the number of counts obtained for each category. The third column (frequency) denotes the ratio of counts for a particular category to the total number of counts for all categories. The fourth column lists the magnitude of the progression factor for each category. The fifth column (product) is derived by multiplying the values of columns three and four of the same category number. The calculated index is the sum of the individual products in the fifth column.

SECTION 10

ULTRASONIC AND AMS 2301 CORRELATION STUDY

The present accepted practice for rating cleanliness of aircraft quality steels is largely governed by procedures set forth under Aerospace Materials Specification 2301 which details the inspectional method, analysis and qualification requirements of semifinished material. The method consists of utilizing magnetic particle inspection to detect and then experimentally measure the length of non-metallic inclusions on select surfaces obtained by step down machining or quarter sectioning.

The correlation study was conducted by ultrasonically inspecting a 14 inch length of 4140 electric furnace vacuum degassed steel billet ($4\frac{1}{2}$ inch square) and comparing the results with magnetic particle severity ratings of step down surfaces. Three equally spaced gates of 0.8 inch depth representing top, middle and bottom layers in the billet were ultrasonically inspected and rated. A one inch layer of material adjacent to the top and bottom billet surfaces was not inspected. Fifteen longitudinal scans 1/4 inch apart were conducted for each gated layer.

The ultrasonic cleanliness ratings obtained for each layer are indicated in Table I. The magnetic particle severity ratings of step down surfaces are shown in Table II. Since the bar was square, AMS severity values were obtained for two individual surfaces. Referring to Table II, the AMS rating of gate 1 and gate 2 indicate a slight difference in inclusion severity whereas an appreciable difference is noted ultrasonically. Examination of the results for gate 3 indicate a substantially lower AMS inclusion severity than gate 1, however ultrasonic findings indicate that gate 1 and gate 3 are of comparable cleanliness.

Thus, a low degree of correlation is observed for the two methods which is attributable to the small number of planes that are examined under AMS 2301 specifications. With 0.8 inch gate depths, only four planes are examined in gates 1 and 3. Two planes were examined in gate 2.

SECTION 11

ULTRASONIC AND MODIFIED MAGNETIC PARTICLE INSPECTION CORRELATION STUDY

While the AMS inspectional procedure furnishes some measure of cleanliness acceptance between producer and consumer, it is severely limited in terms of insufficient material sampling. For example, with a 5" long x 5" wide x 5" high steel bar, the area of inspection required under AMS 2301 for a step down bar with steps of 1/5H, 2/5H, 3/5H, 4/5H and H entails 250 square inches. A complete inspection by successive removal of 0.002 inch from the height dimension yields approximately 62,500 square inches (250:1 ratio). Therefore, to provide more inspection coverage than required under AMS 2301 and maintain a reasonable inspection schedule, material was removed and examined at 0.050 inch steps which provides a complete to partial inspection coverage of 25:1.

11.1 Specimen Treatment and Examination

Fourteen inch length segments of 5 inch round corner square AISI 4340 steel billets representing various steel making practices were given a cursory ultrasonic examination to separate certain cleanliness levels. These segments (coupons) were inspected in the initial condition, namely, as rolled with a mill scale. Several coupons exhibiting different cleanliness levels were then selected for more intensive ultrasonic examination.

11.1.1 Ultrasonic Inspection

Prior to inspection, specimen coupons were surface ground to obtain opposite and parallel flats for two surfaces. For all ultrasonic tests, a 2 inch water path and scanning speed of 25 ft/min were maintained. The area of billet inspection was confined to vertical limits starting at 1 inch below the top surface and extending to 1 inch above the bottom surface. The one inch layers of material adjacent to the top and bottom surfaces were not inspected due to a wide front reflection trace which was prevalent at the sensitivity level required.

The vertical zone of billet inspection (1 1/2 inches above to 1 1/2 inches below billet center) was divided into five equally spaced gates of 1/2 inch which allowed a 1/8 inch gap between adjacent gates to prevent overlapping of gate boundaries. Gates 1, 2 and 3 were inspected and the billet then rotated 180° to inspect gates 4 and 5. Figure 14 shows the gated areas of inspection for 5 inch round corner square coupons.

Initially three coupons were examined by conducting twenty-one longitudinal scans that were 0.2 inch apart in each gated area. Tables III through V show the calculated ultrasonic cleanliness indices at each gated level.

11.1.2 Magnetic Particle Inspection

After ultrasonic inspection, each coupon was austenitized at 1550 F, oil

quenched and tempered to a hardness level of Rc 30. Each gated layer was then inspected in 0.050 inch increments by the wet circular magnetic particle procedure in accordance with Aerospace Materials Specification 2640. Inclusion lengths were measured and recorded as to transverse location in the billet for comparison with ultrasonic findings of the same lateral position. Thus, ultrasonic and magnetic particle ratings were obtained for each longitudinal scan. Tables VI through VIII list magnetic particle severity ratings for all scans at each gated layer.

11.2 Comparison of Ultrasonic and Magnetic Particle Ratings

From an analysis of the above referenced data, it is readily apparent that the most significant difference in ultrasonic cleanliness rating between the three billets is obtained by averaging the three central scans in the middle gated area. The order of increasing inclusion severity is-consumable electrode vacuum arc remelt (CEVAR 21), open hearth (OH 3H) and electric furnace vacuum degassed (EFVD IF). However, using the same criteria of averaging the three central scans with magnetic particle rating, the order of increasing inclusion severity is CEVAR 21, EFVD IF and OH 3H. The change in order of the last two coupons prompted the question as to whether a 0.2 inch lateral displacement of the transducer was of too great a magnitude to properly inspect the specimen width. To test this theory, a control specimen was scanned in which lateral indexing was conducted in 0.2 and 0.05 inch increments. The results of this experiment demonstrated that a number of large inclusions were undetected by lateral indexing of the crystal in 0.2 inch increments. This is attributed to the configuration of the crystal lens which focuses the energy into the shape of a cone having a small apex.

11.3 Reevaluation with Refined Lateral Adjustments

Additional coupons of AISI 4340 steel (5 in. x 5 in. x 14 in. long) were sectioned, surface ground and heat treated (austenitized at 1550 F followed by an air cool). The gated areas of ultrasonic inspection were identical to the three previous coupons. However, the center gate of each specimen was scanned in much greater detail by conducting eighty-one longitudinal passes that were 0.05 inch apart. The remaining gates (1, 2, 4 and 5) were scanned by conducting twenty-one longitudinal passes that were 0.2 inch apart. The ultrasonic cleanliness results are shown in Tables IX and X.

All coupons were then hardened, tempered to Rc 30 and inspected using magnetic particle technique by successive removal and examination of material surface at discrete layers of 0.050 inch. The resulting magnetic particle severity ratings are presented in Tables XI and XII. The values shown were obtained by summing the number of various length inclusions for all layers within a gated area and applying the appropriate weighting factor corresponding to the inclusion length. The area used to calculate the rating was the area commensurate with a single layer (0.2 in. wide x 13.0 in. long).

11.3.1 Correlation of Center Scans

Referring to Tables IX and X, the order of increasing ultrasonic inclusion

severity (calculated index) is OH 3G (5.8), EFVD 2C (6.8), OHVD 3A (12.3) and OH 2G (1338.2). These values represent the average cleanliness index of twelve passes (-0.3 to +0.3 inch of longitudinal center) along the middle gate (2 1/4 to 2 3/4 from billet top surface). The order of increasing magnetic particle severity ratings (average of twelve longitudinal passes) is OH 2G (0.00), EFVD 2C (0.19) OHVD 3A (0.45) and OH 3G (7.82).

With the exception of OH 2G and OH 3G, the two rating methods compare favorably with respect to ranking of inclusion severity. With open hearth 2G, a more severe inclusion rating is evident utilizing ultrasonic inspection in contrast to magnetic particle rating which indicated fewer and smaller inclusions. It is highly conceivable that large inclusions were present in material layers of 0.050 inch between adjacent inspection levels and went undetected during magnetic particle examination. Considering the opposite condition noted with open hearth 3G coupon, the magnetic particle severity rating ranked highest and the ultrasonic rating was minimal. This may be the result of an incorrect location of longitudinal center with respect to both rating systems. For example, if a second set of twelve adjacent scans (displaced 0.1 inch from the original set) is selected, a considerably higher cleanliness index is obtained. The order of increasing inclusion severity for both methods then became:

ULTRASONIC RATING	MAGNETIC PARTICLE RATING
EFVD 2C (6.4)	OH 2G (0.00)
OHVD 3A (12.3)	EFVD 2C (0.19)
OH 3G (15.9)	OHVD 3A (0.45)
OH 2G (1338.2)	OH 3G (7.82)

11.3.2 Correlation with Full Coupon Width

The maximum surface area covered by ultrasonic inspection (entry surface) was approximately 49.4 square inches (3.8 inch width x 13.0 inch length). Magnetic particle severity ratings were calculated for all levels of each gate using the above value and are shown in Figures 15 through 18. A comparison of magnetic particle severity ratings with ultrasonic cleanliness ratings is presented only for the center gate of each coupon which was inspected by laterally indexing at 0.050 inch intervals. Ultrasonic cleanliness ratings of each center gate was determined by adding the number of counts obtained in each category for all eighty-one scans. The total number of counts and corresponding mathematical treatments for each coupon are indicated in Figures 19 through 22. The order of increasing ultrasonic inclusion severity is as indicated below, along with corresponding magnetic particle ratings:

ULTRASONIC SEVERITY RATING	MAGNETIC PARTICLE SEVERITY RATING
EFVD 2C (2.9)	EFVD 2C (0.0045)
OHVD 3A (3.3)	OHVD 3A (0.022)
OH 3G (3.9)	OH 3G (0.12)
OH 2G (231.4)	OH 2G (0.0055)

The order of inclusion severity is identical for both methods with the exception of one coupon, namely OH 2G which is probably due to concealment of large inclusions in layers between adjacent inspection levels.

In both instances (central and expanded areas), a positive trend of cleanliness ranking is observed between magnetic particle and ultrasonic inspection methods. Attainment of an exact correlation presents difficulties in that only 2% of the total volume of material is inspected using magnetic particle techniques and the ultrasonic transducer senses inclusion area rather than length as stated in AMS 2301 specification.

SECTION 12

MAGNETIC PARTICLE EVALUATION WITH 0.005" STEPS

Additional magnetic particle tests were conducted in which AISI 4340 material was inspected at 0.005 inch depth increments to obtain a much greater inspection coverage. A 5" wide x 5" high x 14" long normalized billet was ultrasonically examined by conducting forty-one longitudinal scans in the central region of the billet. The volume of material inspected corresponded to a coupon with dimensions of 2.2" wide x 0.5" high x 13.0" long. After ultrasonic inspection, the coupon was hardened and tempered to Rc 30, sectioned from the billet and rated for inclusion severity by examining one-hundred surfaces (0.005" increments) using magnetic particle technique. The ultrasonic severity ratings obtained for all scans of the coupon is shown in Table XIII. Magnetic particle ratings associated with each lateral scan are also listed in Table XIII.

The AMS severity ratings for all surfaces (covering full coupon width)are shown in Table XIV. It should be noted that a significant difference in severity rating can occur between adjacent levels that are 0.005 inch apart. This is evident with surfaces No. 7 and 8 which indicated severity magnitudes of 0.09 and 0.47.

Magnetic particle inspection per se is a satisfactory method of detecting inclusions, however, in order to obtain an accurate assessment of internal cleanliness, a considerable increase in the number of inspection surfaces are required in contrast to the small number specified in AMS 2301. Additionally, the lateral limits of magnetic particle inspection should be confined to central regions of billets which generally display higher inclusion severity. The AMS severity rating is derived by dividing the weighted distribution of inclusions by the specimen area. If the area represents the entire billet width, a less severe rating results due to the diluting effect of cleaner zones that are remote from the center.

Although step down testing is an alternate method to quarter sectioning as specified by AMS 2301, the latter method is particularly objectionable in that the examination area generated is largely comprised of areas remote from the center. A graph of ultrasonic severity versus magnetic particle severity is presented in Figure 23. The plotted ultrasonic values represent the maximum value of the four cleanliness indices obtained in each 0.2" lateral zone. As can be noted, a positive correlation is apparent and indicates that cleanliness magnitudes determined with the subject system are definitely related to magnetic particle cleanliness findings when performed in minute detail.

SECTION 13

ULTRASONIC AND METALLOGRAPHIC CORRELATION OF INCLUSIONS

An ultrasonic cleanliness index or material rating is devised by mathematically treating the percent count obtained for a category with an arbitrarily selected weighting factor. The ultrasonic category, however, not only represents a certain voltage level but in addition relates to inclusion area as sensed by the transducer.

13.1 Effective area of Ultrasonic Beam

Although the transducer diameter is 3/4 inch, the beam pattern in steel is considerably smaller due to the focusing effect of the lens and angular distribution of energy. The effective area of ultrasonic beam coverage was determined by aligning the transducer over a steel calibration block containing a 1/64 inch diameter flat bottom hole (2 1/2 inch from entry surface) and laterally adjusting the transducer in the x-y plane to obtain the maximum video signal amplitude. A dial gauge was then attached to the transducer holder for accurate measurement of transducer displacement from alignment center. Ultrasonic video amplitudes were measured for a multiple number of positions distant from the center of alignment. The limits of transducer displacement for maintaining 97% of maximum signal amplitude is $\pm$ 0.025 inch as indicated in Figure 27(a). However, the transducer senses the hole with an 80% decrease in signal amplitude at displacements of $\pm$ 0.160 inch. If the signal amplitude at alignment center is 2 inches which corresponds to ultrasonic category 16, the amplitude after the transducer is displaced 0.160 inch is 0.40 inches which corresponds to category 4. Therefore, as the transducer approaches alignment center for a given size inclusion, an increase in amplitude is continuously registered until the maximum amplitude is reached. If the maximum amplitude of the defect corresponds to category 8, counts would also be registered in other categories of smaller magnitude such as 2, 4, 5, 6 and 7. However, since this condition exists for all size inclusions, the cumulative inclusion counts will reflect constant factors contributing to inclusion severity.

It should be recognized that the effective area of ultrasonic coverage is dependent upon free water path and metal travel. Additional tests were conducted to determine the area of ultrasonic beam coverage for 1 1/2 and 3 1/2 inch metal travel to the 1/64 inch diameter flat bottom hole (water path held constant at 2 inches). The fields of beam coverage are shown in Figures 27(b). A pictorial view showing the converging and diverging conical shape of the beam with intersecting planes indicating the effective area of ultrasonic coverage at three select material depths is presented in Figure 27(c).

A cursory examination was conducted with two transducers to determine how closely identically designed transducers responded with respect to beam pattern and reproducibility. This experiment was conducted in a similar manner to the above experiment with the exception that a 1/16 inch diameter ball served as a target defect. Figures 27(d), and 27(e) show the effective areas of coverage for 5MC and 10MC transducers.

13.2 Ultrasonic Location and Measurement of Various Size Inclusions

To gain information as to the relation between category magnitude and inclusion area, several discrete inclusions representing various categories were located with a static transducer and examined metallographically. Ultrasonic location of the inclusions was effected by manually scanning a billet until a certain voltage level was noted and verified for category magnitude by computer print out. With the transducer positioned over a select area, inclusion depth was established by measuring the distance between the front reflection trace and inclusion trace as noted on the UM 721 scope screen. Upon marking and sectioning the select areas, samples were obtained in which the inclusions were located near the center of a 0.3 inch flat disc. Each disc was then successively ground, polished and examined with a light microscope at 0.003 inch increment through the entire thickness (0.3 inch). Photographs were taken at applicable levels that indicated significant size inclusions.

The one photograph which indicated the largest inclusion for each sample representing categories 1, 3, 9 and 15 was photographically enlarged to five hundred magnification after which inclusion area was measured with a planimeter. Figure 24 shows a plot of inclusion area versus ultrasonic category. Photomicrographs of inclusions which represent categories 3, 9 and 15 are illustrated in Figures 25 and 26.

SECTION 14

ULTRASONIC CALIBRATION STANDARDS

A number of 5 inch round corner square billets were heat treated (austenitized at 1550 F, followed by an air cool), surface ground and inspected with the computerized quality control system for the purpose of establishing ultrasonic cleanliness standards. Four coupons (5 inch x 5 inch x 1/4 inch long) that indicated diverse cleanliness levels were selected and examined extensively in the center gated regions (2 1/4 to 2 3/4 inches from billet top surface), Tables XIV and XV show the complete ultrasonic results obtained for each coupon. The maximum index for each standard is underlined and corresponding cleanliness histograms are presented in Figure 28.

The four standards are AISI 4340 steel billets produced by different steel making practices. Standards number one through four are electric furnace vacuum degassed, open hearth vacuum degassed, open hearth and consumable electrode vacuum arc remelt, respectively.

The cleanliness rating of each standard was obtained by selecting the longitudinal pass that indicated the maximum calculated index.

In order to duplicate the cleanliness results the operator should adhere to the following requirements:

(1) Calibrate ultrasonic station as detailed in Section 15.1.
(2) Maintain a water path of 2 inches.
(3) Use a 5 MC, 3/4 inch diameter lithium sulfate transducer with a 7 inch focal length in water.
(4) Accurately position transducer over coupon area that corresponds to standard's index rating, and
(5) Accurately set gate start and gate length.

SECTION 15

OPERATING AND MAINTENANCE PROCEDURES

15.1 Ultrasonic Station - Operating Procedure

The ultrasonic main frame (UM 721), an analog interface module and a digital interface component are contained in a single steel cabinet which is mounted on a portable wooden base. A constant voltage transformer (500 VA harmonic neutralized) is installed in the base of cabinet to ensure a uniform input voltage to the ultrasonic components. In addition, a 2 KW electrostatically shielded isolating transformer is mounted at the rear of the cabinet base. Electrical connectors leading to the ultrasonic and computer station are inserted into this unit to minimize noise originating from A.C. power lines. A block diagram indicating current flow through principal components of the ultrasonic station is shown in Figure 29.

Schematic diagrams of the analog interface and digital interface are shown in figures 30 and 31. A diagram of the synchronization pulse train section is shown in Figure 32.

Figure 33 through 35 show photographs of the ultrasonic main frame, analog interface and digital interface. A listing of electronic parts associated with the analog interface module and ultrasonic rack is detailed in Figure 36.

15.1.1 Ultrasonic Main Frame

1. Connect power cord from isolation transformer to 115 V 50/60 cycle single phase outlet.

2. Turn on main switch located on lower part of front cabinet (allow approximately 2 hour warm-up period for UM 721).

3. With transducer* attached to bridge positioner, connect co-axial cable to "T" or "R" jack on UM 721 (with 25 ft. RG62B/V cable use "T" jack - 6 ft. cable use "R" jack).

   * Note: Do not leave transducer immersed in bath for extended periods when system is not in use.

4. Set UM 721 controls as follows:

(a)	Sweep delay	2
(b)	Sweep	1 x 1
(c)	Sweep Toggle Switch	Dial position
(d)	Pulse length	Minimum (full CCW)
(e)	Pulse Tuning	Rotate knob to obtain maximum trace amplitude on UM 721 screen.
(f)	Reject	Off
(g)	Test Switch	Normal
(h)	Frequency	Frequency of transducer

(i)	Gate sync.	Main pulse
(j)	Gate Switch	Off
(k)	Sensitivity 1	Approx. 18.0 db
(l)	Sensitivity 2	Approx. 15.0 db
(m)	Sensitivity 3	Approx. 13.0 db

15.1.2 Calibration of Ultrasonic Station

1. Um 721

(a) Using a steel step block (Figure 37) in which 1/64 inch diameter flat bottom holes have been machined in each step, vertically position the transducer over the block to obtain a 2 inch water path.

(b) Turn gate channel selector switch to No. 1 position and turn sweep delay vernier knob such that first front and first back reflection appear on scope screen.

(c) Adjust sensitivity No. 1 to obtain approximately 1 inch amplitude of back reflection trace.

(d) Align transducer for perpendicularity with synthetic defect in test block by adjusting inclination controls to obtain maximum amplitude from back reflection trace.

NOTE: Adjustments for perpendicularity must be conducted in two planes 90° to each other.

(e) Reset sensitivity No. 1 to approximately 18.0 db and laterally adjust (x-y) the transducer over the 1/64 inch diameter hole in step 1 (2 inch thickness) to obtain a maximum amplitude defect trace.

(f) After maximizing trace, readjust sensitivity control No. 1 to obtain a 2 inch amplitude defect trace on scope screen. Record this setting.

(g) Turn gate channel selector switch to No. 2 position and relocate transducer over 1/64 inch diameter hole in step 2 (3 inch thickness).

(h) Maximize defect trace amplitude by x-y adjustment of transducer and adjust sensitivity control No. 2 to obtain a 2 inch amplitude trace on scope screen. Record this sensitivity level.

(i) Repeat for step 3 (4 inch thickness) using gate channel selector No. 3 and sensitivity control 3.

These sensitivity settings are used for inspecting gates 1, 2 or 3.

15.1.3 Analog Interface Module

The analog interface was designed to condition the ultrasonic output signal for acceptance by the analog to digital converter. A synchronization pulse train which triggers the analog to digital converter to sample the ultrasonic signal at a precise time is operational upon turning on the main power switch. The analog interface controls are positioned as follows:

15.1.3.1 Digital Voltmeter Controls

1. Range — For selecting multiple voltage levels and calibrate position. Under normal operation, set range control at 10 volt position.

2. Cal — To calibrate instrument, place range control in calibrate position and rotate "Cal" knob until the value of 2.21 is visually displayed.

3. Polarity — Place in minus (-) position.

4. Display — Regulates the duration of voltage display. Rotate to obtain a visual display of voltage every 1 to 2 seconds.

15.1.3.2 Coarse Sensitivity Control

Four levels of sensitivity magnification (1/2, 1, 2 and 3) are available for amplifying the output ultrasonic signal level. In most instances a magnification of 1x can be used. For very clean material set selector to 2x. For very dirty material set selector to 1/2x.

NOTE: Use of 1/2x, 2 x or 3x will necessitate a change of P. factor values to obtain a cleanliness rating comparable with 1x.

15.1.3.3 Operate and Test Switch

1. Operate — In this mode, D.C. analog output signals are routed from the UM 721 main frame, conditioned and delivered to the analog to digital converter. The operate mode is used for normal billet inspection and calibration with reference standards.

2. Test — In the test position, a separate D.C. voltage source contained in the interface module is routed to the analog to digital converter to verify converter accuracy. The level of the voltage is regulated by either of two vernier potentiometer controls (offset and fine sensitivity) and verified by the digital voltmeter.

NOTE: During calibration or billet inspection, transducer lens should be periodically wiped with finger every half hour to remove air bubbles.

15.1.3.4 Offset and Fine Sensitivity Controls

Two dial potentiometers located on the analog interface module are provided to adjust the high (-10 volts) and low (0 volts) ends of the ultrasonic output voltage to correspond with a certain defect trace amplitude on the scope screen.

To obtain correct dial settings, transducer must be accurately positioned over synthetic defect (1/64 inch diameter hole) in calibration standard (steel step block). Proceed as follows:

1. Align transducer over 1/64 inch diameter hole in step 2 of reference standard to obtain maximum amplitude of defect signal on scope screen.

2. Turn gate channel selector to No. 2 position and adjust sensitivity No. 2 to a 2 inch defect signal amplitude on scope screen.

3. Without moving transducer, set gate channel selector switch to No.3 position and adjust sensitivity control No. 3 to obtain a 0.2 inch defect amplitude trace on screen.

4. Turn gate switch on and adjust gate 3 start and gate 3 length to enclose defect signal.
   NOTE: Do not set gate length less than 3/8 inch.

5. Set gate channel selector to No. 2 position and adjust gate 2 start and gate 2 length to bracket defect signal (2 inch amplitude).

6. Rotate fine sensitivity control to obtain a reading of -0.97 ± 0.05 volts on the digital voltmeter.

7. Reset gate selector switch to channel No. 3 and rotate offset control to obtain -9.70 ± 0.05 volts on voltmeter.

8. Relocate gate selector switch to channel No. 2 and verify that voltage is -0.97 ± 0.05. If not, readjust fine sensitivity dial to obtain this reading.

9. Repeat for channel 3, continuously adjusting the fine sensitivity control to obtain -0.97 ± 0.05 volts for the 0.2 inch amplitude and the offset control to obtain -9.70 ± 0.05 volts for a 2 inch amplitude. This will require practice.

15.1.3.5 Overload Indicator

Since the computer will not register voltages in excess of -10 volts, audible and visual alarms are located on the analog interface panel to indicate if overload voltages are encountered. Once energized, the alarm remains on until manually reset by the operator.

15.1.4 Digital Interface Module

A digital interface control is located above the analog interface unit and serves as an input/output station for regulating timing, voltage and impedence compatability with the computer main frame. The following controls and indicators are contained on the interface panel.

1. Auxiliary Contact

   Duplicate occupancy contact switch for manually producing contact closure. Normally left in open position.

2. +10 v and -15 volt toggle switches - These switches are set in the down position.

3. Busy lamp - Lit while computer is assimilating or reporting information.

4. Alarm indicator - Visual and audible indicators are energized when calculated cleanliness index exceeds an allowable stored reference index.

5. Alarm reset - Manually reset by operator to cancel alarm.

15.2 Teletype Station - Operating Procedure

The main line of communication with the computer occurs through the teletype unit (33 ASR) which transmits information on coded paper tape at the rate of 10 characters (rows) per second. A three position switch, on-line/off/local, regulates the mode of teletype operation. Transfer of information between the teletype and computer is solely conducted by the on-line mode. With the switch in the off position, power to the teletype unit is disrupted.

15.2.1 Local Mode

In the local mode, the unit may be used (1) as a conventional typewriter, (2) to punch paper tapes via the keyboard, or (3) to duplicate existing tapes. Since the local mode is primarily used for duplicating tapes, this operation is presented in detail. Both on-line and local use of teletype require turning on computer power switch.

Tape Duplication

(a) Turn computer on by rotating key clockwise in power switch.
(b) Place teletype mode switch in local position.
(c) Place reader unit Start/Stop/Free switch in free position.
(d) Unfasten tape guard lid by releasing latch handle.
(e) Place paper tape in reader unit with off center sprocket holes. on left and place feed wheel sprockets in tape sprocket holes.
(f) Close Tape lid.
(g) Push "on" button of punch unit.
(h) Place reader control switch in start position. The reader will automatically advance the tape during which time an exact duplicate is perforated and advanced through the punch unit. The reader drive wheel automatically halts at the end of tape at which time the punch will also halt.
(i) Push "off" button on punch unit.
(j) Place control switch of reader unit in stop position.
(k) Remove tapes from reader and punch unit.

15.2.2 On Line Mode

The on-line mode is operated in the same manner as local mode except the information contained on the tape is transmitted to the computer upon positioning the switch in the on-line position and selecting the appropriate address on the computer switch register and pressing Load Address and Start keys. (See Section 15.3 - programming of computer)

15.2.3 Tape Description

The paper tape on which coded programs are contained is 1 inch wide with a column of lead holes (1/32 inch diameter) and larger perforations (1/16 inch diameter) which represent binary ones. Binary zeroes are identified by an omission of perforation (blank). To express a single 12-bit computer word, two rows of perforations or blanks are required. The first row (Columns 1 through 6) contains the left side of the word and the second row (Columns 1 through 6) contains the right side of a 12-bit word. A perforation in Column 7 indicates the presence of an address. At the initial and final lengths of a tape, a series of perforations on Column 8 denote leader and trailer holes, respectively, which facilitate handling.

15.2.3.1 Rim Format

The Rim format tape shown in Figure 11 contains an information pattern in the form of address A-content A, Address B - Content B, etc. An address marker or perforation in Column 7 will appear in every fourth row. The loading address format of a Rim format tape is always 7756 (octal).

15.2.3.2 Bin Format

The Bin format allows a longer program to be placed on a shorter tape by placing the instructions in consecutive locations. The Bin format tape is shown in Figure 12. Note that an address is specified followed by a series of contents (block). Since the addresses of a single block are in consecutive order, it is only necessary to list the contents after a starting address is specified. For example, if there are thirty instructions in a block, only one address (starting) and thirty contents are listed in contrast to the Rim format tape which would require the listing thirty addresses and thirty address contents. The Loading address for a Bin format tape is 7777 (octal).

15.2.3.3 Tape Inspection

Since paper tapes are relatively delicate, visual inspections should be made to ascertain whether the tape is free of discernible defects (tears, frayed hole edges, etc.) prior to loading. If there is any indication of tape wear or uncertainty as to tape read-in errors, prepare a duplicate tape via the teletype punch unit.

15.2.3.4 Special Keyboard Functions

Certain keys on the teletype keyboard when pressed individually or in combination perform special functions such as:

(a) Produce Sprocket or Feed holes
1. set teletype mode switch to local position
2. press "on" button of punch unit
3. press and release "here is" key on keyboard

(b) Produce Leader - Trailer holes
1. set teletype mode switch to local position
2. press "on" button of punch unit
3. simultaneously press and hold "CTRL", "Shift", "REPT" and "P" keys. Release keys after desired length of leader or trailer section is punched.

(c) Rub Out
If a numeric error is made during preparation of P. factor tape, press rub out key.

15.3 Computer Station - Operating Procedures

The computer station is comprised solely of the computer main frame which performs binary operations on 12 bit 2's complement numbers.

15.3.1 Specifications

1. Power requirements - 115 volts, 60 cycles, single phase, 7.5 amps.

2. Power dissipation - 780 watts.

3. Digital Signal Levels - ground and -3 volts.

4. Cycle Time - 1.5 micro seconds.

5. Core Memory Size-4096 words.

Since the only language directly interpretable by the computer is binary machine language, the binary number system is described.

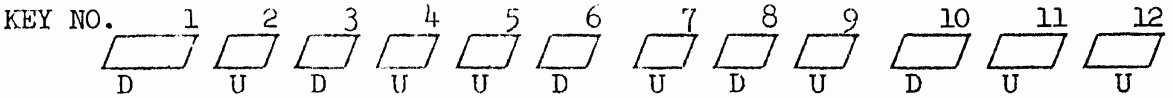
15.3.2 Binary Number System

An integer or decimal number can be represented by a series of ones (1) and zeros (0). The position of the 1 or 0 in a series determine the power of 2 that is applicable. For example: The binary number of 1001 converted to the decimal equivalent becomes $1(2^3)+0(2^2)+0(2^1)+1(2^0)$ or 9. Larger decimal numbers can be expressed by simply extending the pattern of ones and zeros. For example: The binary number of 1011101101 represents $1(2^9)+0(2^8)+1(2^7)+1(2^6)+1(2^5)+0(2^4)+1(2^3)+1(2^2)+0(2^1)+1(2^0)$ and is equivalent to decimal number 749. However, since the major registers of the computer are 12 bits long and divided into four equal sections of 3 bits each, each section can be represented by an octal number (0 to 7) produced by entering binary ones and zeros through the computer switch register. A binary 1 in a register is evidenced by a lit port or ports in the 12 bit length. For example, with the program counter register, the ports that are darkened below represent unlit ports or binary zero and the unshaded ports represent lights or binary ones. The register is read as:

● 0 ●	0 0 ●	0 ● 0	● 0 0
0 1 0	1 1 0	1 0 1	0 1 1
2	6	5	3

Therefore, the contents of the program counter is 2653. This number is placed in the program counter via the switch register which also operates in the binary number system. When a switch register key is placed in the up position, binary 1 is entered. In the down position, binary 0 is obtained. Since each word is 12 bits in length, there are 12 keys in the switch register which again are divided into 4 segments of 3 keys per segment. To load 2653 in the program counter set the switch register keys as follows:

SWITCH REGISTER



D = Down

U = Up

The following list is presented to indicate a range of octal numbers that are obtainable by setting various keys (12) in the switch register.

Switch Register												Octal Number
Key No.	1	2	3	4	5	6	7	8	9	10	11	12	
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	1	1
	0	0	0	0	0	0	0	0	0	0	1	0	2
	0	0	0	0	0	0	0	0	0	0	1	1	3
	0	0	0	0	0	0	0	0	0	1	0	0	4
	0	0	0	0	0	0	0	0	0	1	0	1	5
	0	0	0	0	0	0	0	0	0	1	1	0	6
	0	0	0	0	0	0	0	0	0	1	1	1	7
	0	0	0	0	0	0	0	0	1	0	0	0	10
	0	0	0	0	0	0	0	0	1	0	0	1	11
	0	0	0	0	0	0	0	0	1	0	1	0	12
	0	0	0	0	0	0	0	0	1	0	1	1	13
	0	0	0	0	0	0	0	0	1	1	0	0	14
	0	0	0	0	0	0	0	0	1	1	0	1	15
	0	0	0	0	0	0	0	0	1	1	1	0	16
	0	0	0	0	0	0	0	0	1	1	1	1	17
	0	0	0	0	0	0	0	1	0	0	0	0	20
	0	0	0	0	0	0	0	1	0	0	0	1	21
	0	0	0	0	0	0	0	1	0	0	1	0	22
	0	0	0	0	0	0	0	1	0	0	1	1	23
	0	0	0	0	0	0	0	1	0	1	0	0	24
	0	0	0	0	0	0	1	1	0	0	1	0	62
	0	0	0	0	0	1	1	0	0	1	0	0	144
	0	0	0	0	1	1	0	0	1	0	0	0	310
	0	0	0	1	0	0	1	0	1	1	0	0	454
	0	0	0	1	1	0	0	1	0	0	0	0	620
	0	0	0	1	1	1	1	1	0	1	0	0	764
	0	0	1	0	0	1	0	1	1	0	0	0	1130
	0	0	1	0	1	0	1	1	1	1	0	0	1274
	0	0	1	1	0	0	1	0	0	0	0	0	1440
	0	0	1	1	1	0	0	0	0	1	0	0	1604
	0	0	1	1	1	1	1	0	1	0	0	0	1750
	0	1	1	1	1	1	0	1	0	0	0	0	3720
	1	1	1	1	1	0	1	0	0	0	0	0	7640
	1	1	1	1	1	1	1	1	1	1	1	1	7777

After the keys are positioned, press the load ADD key (to the right of the switch register) down. The octal number corresponding to the switch register setting is then indicated by lights in the program counter register.

15.3.3 Computer Panel Controls and Registers

Manual control of the computer is accomplished by keys and switches located on the computer console panel. The function of these controls are as follows:

1. Panel lock switch - a key operated switch which when turned clockwise locks out or inactivates the command keys for executing an instruction.

   Power Switch - Key operated switch which controls release and removal of power to computer. The computer is turned on by a clockwise rotation of the key.

   Start - Initiates the computer program by disrupting the programs interrupt circuits.

   Load Address - Places the contents of the switch register in the program counter register.

   Deposit - Takes the contents of switch register and places in memory buffer. This key is normally down and must be lifted to execute command.

   Examine - Indicates the contents of the memory core for a specific address shown in the program counter register.

   Continue - Continues execution of the program from the address shown in program counter register.

   Stop - Halts the program run.

   Single Step
Single Instruction - Not normally used. Only applied for special diagnostic tests in which the program is examined at each cycle or instruction. These keys should be placed in the down position (off).

   Data Field
(Switches and indicators) - Nonfunctional, to be disregarded.

   Inst. Field
(Switches and indicators) Nonfunctional, to be disregarded.

   Switch Register -Provides a means of manually entering 12 bit words of binary language into the computer. Used as a sense switch after the required programs are loaded.

15.3.4 Programming Computer

15.3.4.1 Preliminary Procedure

a. Insert plug of power cord in isolation transformer which is connected to 115 v 60 cycle single phase outlet.

NOTE: Connect computer to an isolated electrical circuit. Red indicator lamp on computer rear panel indicates current is being delivered to computer.

b. Set main power switch on computer rear panel to "on" position.

NOTE: A two position (-15 v and + 10 volts) toggle switch and adjustable voltage control on rear panel are used with diagnostic tests and are disregarded for normal inspectional procedures.

c. Place key in panel lock switch located on front panel and turn counter clockwise to unlock panel keys.

d. Place key in power switch (lower left of front panel) and rotate clockwise to turn computer on.

15.3.4.2 Read-in Mode Program

The initial program (RIM) must be manually entered in core memory by the operator using the switch register keys and certain instruction keys to the right of the switch register. The following addresses and address contents are loaded:

Address	Content
7756	6032
7757	6031
7760	5357
7761	6036
7762	7106
7763	7006
7764	7510
7765	5357
7766	7006
7767	6031
7770	5367
7771	6034
7772	7420
7773	3776
7774	3376
7775	5356
7776	0000

a. Set 7756 in the switch register.

b. Press Load Address Key.
(Verify that 7756 appears in program counter register)

c. Set 6032 in switch register.

d. Lift Deposit key.
(Program counter will automatically advance to next address of 7757. Previous address of 7756 will appear in the memory address and 6032 will appear in memory buffer.)

e. Set switch register to 6031.

f. Lift Deposit key.
(Verify that 6031 appears in memory buffer and program counter shows next address of 7760 for deposit of contents 5357)

g. Set switch register to 5357.

h. Lift deposit key.

i. Repeat this procedure for the remaining list of contents. After last content is deposited, 7777 will appear in the program counter, 7776 will appear in the memory address and 0000 will appear in the memory buffer.

j. The entire RIM mode may be verified by setting 7756 in the switch register, pressing Load Address and pressing examine key. 6032 should appear in the memory buffer. Each successive time the examine key is pressed, the contents will appear in sequential order.

k. If an error is encountered, it is not necessary to restart at the initial address (7756).

Set the address of the incorrect content noted in the switch register and press Load Address. For example, if the contents of address 7772 indicated 7440 instead of 7420, set 7772 in switch register and press Load Address. Next, set the correct content (7420) in switch register and lift Deposit key. The content (7420) will then appear in the memory buffer.

15.3.4.3 Binary Loader Program (BIN)

The next step after manual insertion of Rim loader consists of automatically loading the Bin Loader program tape (Tape No.1) via the teletype reader unit. To accomplish loading proceed as follows:

a. Place reader control switch in free position.

b. Set teletype mode switch to on-line position.

c. Lift tape guard lid of reader unit and place Bin loader tape in unit so that feed wheel teeth engage feed holes in tape.

d. Close tape guard lid.

e. Set 7756 in switch register.

f. Press Load Address key.

g. Press Start key.

h. Set reader unit control key to start position.
Tape will advance through the unit and halt when the end of the tape is reached.

i. Set reader control switch to free position and remove tape by lifting tape guard cover.

15.3.4.4 Billet Analysis Program

The next program tape for insertion is the billet analysis program which consists of two Program parts on a single tape (Tape No.2). Instructions contained on the first part of the tape are placed in the lower half of computer memory and instructions on the second part are placed in the upper half of computer memory. This tape (in Bin Format) has an added advantage in that an error check is incorporated in the tape. This is accomplished by the computer making a continuous count of all binary 1's for the address and contents and comparing the total count with a correct value which is punched in a trailing section of the tape. This error check is referred to as check sum and is visually observed for correctness on the memory buffer and accumulator registers at the trailing section of part 1 and part 2. To enter the billet analysis:

a. Place tape in reader unit (same procedure as previously carried out with Bin Loader).

b. Set 7777 in switch register.

c. Press Load Address key.

d. Press Start key.

e. Place reader unit control switch in start position. Tape will automatically feed through reader unit and come to halt after the first part of tape is completed (approximately 6 minutes). At this point (1st check sum) check computer to verify that 7402 appears in the memory buffer (by indicating lights) and 0000 is shown in the accumulator. If check sum is correct, proceed as follows.

f. Press Continue key. Second part of tape will advance through the reader unit until the trailer section of the tape is reached and halt is encountered.

g. Check second check sum to ascertain that 7402 appears in memory buffer and the accumulator is 0000. If register indicates the correct check sum, the computer is properly programmed and ready for the operator to select the desired mode of operation.

15.4 Modes of Computer Operation

Various modes of operation are available and can be entered by selection of certain switch register keys which act as mode sensors after the Rim, Bin and billet analysis programs have been loaded in computer memory.

15.4.1 Billet Analysis Mode

This is the primary mode of operation of the system. To start the program for the billet analysis mode and all modes proceed as follows:

1. Set 0200 in Switch register
2. Place teletype switch in on-line position
3. Press Load Address key
4. Press Start key
5. Teletype unit will print out "Ultrasonic and Computer System".
6. To enter billet analysis mode:
   (a) Set 0000 in switch register
   (b) Press Continue key
   Note: If busy lamp was lit, pressing continue key should cancel light.
   (c) On the mnemonic symbol panel which displays status of computer or memory reference instruction, the "Run" indicator should be lit.
   (d) Closing and opening of occupancy contact switches (during a billet scan) instructs the computer to acquire, store, process and report data.
   Note: With 0000 set in switch register, keys 11 and 12 are in down position thus P. factor set No. 1 is in use. For a different P. factor set, select appropriate combination of keys no. 11 and 12.

15.4.2 Calibrate 0 Mode

This mode was designed to check the accuracy of the analog to digital converter by the operator setting a known input voltage to the A/D converter terminals and verifying if the correct category is reported. The voltage levels that are set to correspond to the mid-point of categories are as follows:

Category	Mid-Point Voltage Level (D.C.)
1	-0.31
2	-0.94
3	-1.56
4	-2.19
5	-2.81
6	-3.44
7	-4.06
8	-4.69
9	-5.31
10	-5.94
11	-6.56
12	-7.19
13	-7.81
14	-8.44

Category	Mid-Point Voltage Level (D.C.)
15	-9.06
16	-9.69

1. To obtain the desired voltage corresponding to one or several of the categories proceed as follows:

   a. Place the ultrasonic interface switch (operate/test) in test position.

   b. Rotate fine sensitivity and offset control to obtain the desired voltage (observe digital voltmeter as fine sensitivity or offset control is adjusted). For example, for midpoint of category 8, adjust controls to obtain -4.69 volts on digital voltmeter.

   c. If computer is on and in "Run" state (check mnemonic symbol indicators), lift switch register key No. 1.

   d. Teletype should print out "C8" or the category corresponding to the set voltage continuously (once every second) until key No. 1 is placed in down position.

   e. If computer is not in "run" state, set 0200 in switch register, press load address, Press start, place all switch register keys down and press Continue.

15.4.3 Calibrate 1 Mode

1. Since a billet scan is conducted with this mode, certain settings and controls associated with the ultrasonic station must be positioned (See Section 15.1) with coarse sensitivity set at 1X. Adjust gate start and gate length for desired region of billet inspection. Note: "Run" indicator lamp on computer instruction status panel must be lit.

2. Lift key No. 5 in Switch register.
3. Commence billet scan.
4. Close occupancy contact switch at starting point of billet inspection.
5. Open occupancy contact switch at terminal point of billet scan (Note: a duplicate set of occupancy contact switches can be attached to the side of tank and automatically activated by motorized carriage)
6. Observe print out format. If an abnormally high percentage of counts occur in category 16 (in excess of .05), set coarse sensitivity control at 1/2 x.
7. If counts occur only in categories 1 through 3, set coarse sensitivity control to 2x. Note: Progression factor set for 1/2 and 2 magnification must be altered accordingly to furnish calculated indices commensurate in magnitude with index calculated by using sensitivity 1x and its associated progression factor set.
8. Calibrate 1 Mode is cancelled by placing key No. 5 in down position.

15.4.4 Calibrate 2 Mode

This mode is used in conjunction with the ultrasonic reference standard block. The Transducer must be properly aligned and positioned over reference standard block. After setting reference signal height on scope screen (see Section 15.1)record gain setting and voltage displayed on meter.

1. Lift key No. 4 in switch register (computer indicator light must show "Run" condition)

2. Set occupancy contact switch on digital interface control to "close" position for approximately 2 seconds. Return switch to open position.

3. After calibrate 2 format is printed, check to verify that category which contains counts is correct for set voltage level and signal height.

4. Calibrate 2 mode is cancelled by placing key No. 4 in the down position.

15.4.5 Stored Index Update Mode

This mode permits the operator to alter the stored or reference index directly via the teletype keyboard. Using the teletype and computer stations only, proceed as follows:

1. Lift key No. 2 in switch register (computer must be in "Run" state... check indicator lights on mnemonic symbol panel).

2. Teletype unit will immediately print update mode, stored index and the value of present index. The teletyper will then halt in mid-line.

3. Using teletype keyboard, press appropriate numeric keys for desired new index. Selected numbers are typed and placed in computer memory as teletype keys are pressed.

4. Place switch register key No. 2 in down position.

5. Press "carriage return" key on teletype keyboard.

15.4.6 Performance Factor Update Mode

If a performance factor set differing from the four sets stored in computer memory is required, a new set contained on paper tape is entered via the teletype reader. The procedure for preparing a performance factor tape is detailed in Section 15.5.

1. Lift Key No. 3 in switch register (computer must be in "run" condition) teletype will print out following instructions. "Put new data tape in reader, Load Address 7777, press start, turn on reader. At next halt, turn reader off, Load Address 0200, set S.R. for Mode, Press start".

2. Place Tape containing new performance factor set in teletype reader unit.

3. Set 7777 in switch register.

4. Press Load Address key.

5. Press start key.

6. Set teletype reader switch to start position. Tape will automatically advance through reader and halt when trailer section is reached.

7. Place teletype reader switch in free position and remove tape. Computer is in a halt state. To return to a "Run" state set 0200 in switch register, press Load Address, Press Start. After teletype prints "Ultrasonic and Computer System", set 0000 in switch register and press Continue key.

   Note: When the performance factor set tape was prepared, one of four references was selected by positioning keys 11 and 12 of the switch register in a certain combination. Therefore, to select the new P. factor set, keys 11 and 12 must be set in the manner as programmed. For example if keys 11 and 12 were in the up position when the P. factor set No. A tape was prepared, keys 11 and 12 must be in the up position to retrieve P. factor set No. A from computer memory.

15.4.7 Short Form Mode

This mode was included to provide a rapid means of reporting only the distribution of inclusion counts for a billet scan. To enter this mode, Key No. 6 in the switch register is raised and the sequential procedure detailed for calibrate 1 Mode is applied.

Note: Whenever the computer power switch is turned off, the operator must set 0200 in switch register, Press Load Address key, Press Start key, set 0000 in switch register and press continue key after resumption of power.

15.5 Preparation of Performance Factor Tapes

Although only four sets of performance factors can reside in computer memory at one time, an unlimited number of sets can be prepared and coded on paper tape for insertion into one of four available memory blocks for calculating a cleanliness index. To assist in preparing performance factor tapes, special changeover tapes are used to convert the billet analysis program to a tape preparation program. To utilize the changeover tapes, the computer must therefore contain the billet analysis program in memory.

15.5.1 Changeover Tape No. 3

1. Press Stop key on computer instruction register.

2. Place tape No. 3 (convert billet analysis to tape preparation) in teletype reader unit.

3. Set 7777 in switch register. (Teletype mode switch in on-line position)

4. Press Load Address key.

5. Press Start key.

6. Set teletype reader switch to start position. Tape will automatically feed through unit and halt at mid-point and end of tape.

7. Turn teletype reader switch to free position and remove tape.

8. Set 2000 in switch register.

9. Press Load Address key.

10. Press Start key. A list of instructions is printed by the teletype unit. After the message is printed, set keys 11 and 12 in the switch register to control location of P. factor set in one of four memory blocks.

    a. Block 1 - key 11, down - key 12, down (identification code, 00)
    b. Block 2 - key 11, down - key 12, up (identification code, 01)
    c. Block 3 - key 11, up - key 12, down (identification code, 10)
    d. Block 4 - key 11, up - key 12, up (identification code, 11)

11. Press Continue key, teletype printer will type out the following:

    Performance Factors

    Date Prepared By

    S.R. (Bits 10,11) Identification Code

    P. Fact Set # (previous #1)

    Commentary -

    (a) disregard S.R. (Bits 10,11). This should read switch register (keys 11,12)
    (b) After P. Fact Set # and previous number is typed, carriage will halt.

12. Type in new P. Fact Set #

13. Press "carriage return" key. Teletype printer will type out category 1 and previous P. factor value of category 1.

    (a) Type in new P. factor value for category 1.

14. Press "carriage return" key. Teletype printer will type out category 2 and previous P. factor value of category 2.

    (a) Type in new P. factor value for category 2.

15. Repeat this sequence of operations for all remaining categories. If a numeric error is entered, press rubout key prior to carriage return. If an alphabetic character is accidentally pressed, return to Step 8 and re-enter address 2000.

16. After new P. Factor value is inserted for category 16 and "carriage return" key is activated, press "on" control of teletype punch unit.

17. Press CONTINUE key.

18. Coded tape with new P. Factor values will advance through punch unit and halt after a 12 inch length of trailer section is generated.

19. Press teletype punch unit "OFF" button and remove tape.

20. Additional P. factor tapes may be prepared by starting from step 8. (Set 2000 in switch register, press LOAD ADDRESS, press START key)

15.5.2 Changeover Tape 4

A special tape (No. 4) is provided for conversion from the P. factor tape preparation system to the billet analysis system. Proceed as follows:

1. Place tape No. 4 (changeover from tape preparation to billet analysis) in teletype reader unit.

2. Set 7777 in switch register.

3. Press Load Address key.

4. Press Start Key.

5. Place teletype reader control switch in start position. Tape will feed through reader unit and halt upon reaching trailer section of tape.

6. Place teletype control switch to free position and remove tape from reader.

7. Set 0200 in switch register.

8. Press Load Address.

9. Press Start

10. Printer will type out "Ultrasonic and Computer System".

11. Set 0000 in switch register.

12. Press Continue key.

13. Enter desired mode of operation (billet analysis, calibration, short form, etc.)

15.6 Visual Maintenance

Mechanical inspection or checks should be performed at least once each month with particular attention being given to the air filter in the computer cabinet.

Many hours of computer downtime can be avoided by rigid adherence to a maintenance schedule based on the condition of the air filter. A dirty air filter can cause machine failure through over heating which has a number of deleterious effects.

Ensure good mechanical operation of the equipment by performing the following steps and the indicated corrective action for any sub-standard conditions found:

1. Clean the exterior and the interior of the equipment cabinet using a vacuum cleaner or clean cloths moistened in non-flammable solvent.

2. Clean the air filter. Remove the metal strip just below the power supply control panel by removing the machine screw on both sides, then slide the filter out the back of the machine. Wash the filter in soapy water and dry it in an oven or by spraying it with oil free compressed gas. Spray the filter with Filter-Kote (Research Products Corporation, Madison, Wisconsin), and replace it in the computer.

3. Lubricate door hinges, slide mechanisms, and casters with a light machine oil. Wipe off excess oil.

4. Visually inspect the equipment for completeness and general condition. Repaint any scratched or corroded areas with blue paint or charcoal brown paint.

5. Inspect all wiring and cables for cuts, breaks, fraying, wear deterioration, kinks, strain, and mechanical security. Tape, solder, or replace any defective wiring or cable covering.

6. Inspect the following for mechanical security: keys, switches, control knobs, lamp assemblies, jacks, connectors, transformers, fans, capacitors, elapsed time meter, etc. Tighten or replace as required.

7. Inspect all module mounting panels to ensure that each module is securely seated in its connector.

8. Inspect power supply capacitors for leaks, bulges, or discoloration. Replace any capacitors that have these defects.

15.7 Off-Line Reader/Punch/Printer Test

This off-line test checks the punch, reader and printer without utilizing the computer. The advantages of such a test are:

1. Faults found in the punching or reading of tapes or in the typed sheet can be isolated to either the teletype or computer.

2. No reprogramming is necessary as the computer's memory is left undisturbed.

If an error appears in an off-line test, the malfunction is isolated to the teletype. Errors which are uncovered by on-line tests, but are not found in off-line tests, are computer faults.

The test procedure is to have the teletype read a prepared tape, duplicate it and have its contents typed out by the printer.

A tape is prepared by the operator as follows:

Procedure

1. Turn computer on.
2. Place teletype mode switch in local position.
3. Press punch "on" button.
4. Press "HERE IS" key on keyboard to generate sprocket holes.
5. Simultaneously press and hold "CTRL", "SHIFT", "REPT" and "P" keys in order shown for 2 seconds to produce leader holes.
6. Type a series of alphabets and numbers only such as, ABCDEFG and 1234567890. These characters will simultaneously print out and be coded on Tape.
7. Generate trailer section (same procedure as step 5)
8. Remove tape from punch unit and place it in reader unit.
9. Turn reader on-a duplicate tape will be punched and printer will type out characters as tape advances through reader.
10. Tape in reader will automatically halt at termination of trailer holes.
11. Turn reader and punch off.
12. Remove tapes from reader and punch units.

Analysis

Compare the typed out sheet for correctness with initial sheet; they should be identical. If not, there may be a fault in the reader or printer. Repeat test and if the error reoccurs, or a new error is made, then there is a malfunction in the teletype. Preserve print-out for teletype repair man.

The tapes are checked by placing one tape upon the other and aligning the holes. If any holes appear in one tape but not the other, there is a punch error. Thoroughly clean the punch and repeat test. Reoccurrence of error indicates teletype malfunction. As above, preserve the "faulty" tapes for teletype repairman.

15.8 Off-Line Teletype Keyboard Test

This test is performed after the Off-Line Reader/Punch/Printer Test and prior to any On Line Tests. The purpose of the test is to punch out a tape of approximately 200 characters and then have the teletype reproduce this tape.

Assuming that the Off-Line Reader/Punch/Printer Test has been performed and no errors were detected, then any errors found by this test must be malfunctions caused by the keyboard and/or its connections with its buffer.

Procedure

1. Turn computer on.
2. Turn teletype to local (Off-Line)
3. Turn punch on - reader must be off.
4. Type "here is" character 3 times.

Type 50 to 55 characters using any letters except certain forbidden characters shown below:

here is	alt mode*	line feed *
return*	control	rubout *
repeat	break	space *
shift		

Hereafter, in subsequent tests, these will be called "outlawed" characters. Since they are not printed by the printer; they are of no use in a keyboard test.

5. Type "here is" character 3 times - turn punch off and tear tape off.
6. Press return key to bring carriage into proper position for print-out.
7. Place the generated tape in the reader and turn the punch and reader on. Reader, punch, and printer now operate together.
8. When punch ceases, turn reader and punch off.

Analysis

Compare the original tape and type-out to the new tape and type-out. Any error found in this test must be with the keyboard and/or its connections with its buffer.

If any errors are found, repeat the test and see if the same errors reoccur. Save tapes and print-out sheets to show to teletype repairman.

15.9 On-line Punch Test

This test punches a test tape in a predetermined pattern under the control of SW1 (switch register key No. 1). In addition to checking punch accuracy, this program also evaluates other operations of the punch and reader. These would be the tape drive mechanism and the reader's ability to scan a tape containing all holes.

To run the test, the following are prerequisites: (1) RIM Loader must be in memory and (2) the computer must be programmed with Tape No. 812 (Maintenance On-Line Punch). Once these prerequisites are fulfilled, the test runs under the control of SW1. With SW1 down (the position of the other keys in the switch register is immaterial) the code 377 is punched to provide a leader containing all holes. While this is being punched, the free end of the tape is placed in the reader, being careful not to tear the tape, and the reader is turned on. Then SW1 is set in the up position which causes the code sequence 000 through 377 to be punched without interruption. Also the printer will type out a series of symbols, numbers and letters. The print-out is neglected in this test.

The punch is stopped only when an error occurs or when the stop switch on the computer is depressed.

With SW1 in the up position and punch and reader operating, the program begins checking the tape for punching accuracy as soon as the first nonleader character is read. After each line is read the interrupt or stop facility is activated

to test its operation. This being satisfactory, the character is checked. If an error occurs the incorrect code is displayed in the AC lights and the program halts. Pressing the continue key, the correct code is shown, the AC lights and the test again halts.

The tape drive mechanism is checked by having the punch generate a few feet of leader and examining the tape. If the tape is not being advanced properly, the hole spacing will be irregular or adjacent holes will overlap.

The reader's ability to scan a tape containing all holes is observed while the leader is being read. If it misses a hole in any line the program automatically starts looking for a pattern. This will immediately show up as an error and the test halts with the leader in the reader. The missed holes will correspond to the unlit lights in the accumulator register.

Procedure

1. Turn on computer.
2. Teletype, punch and reader are off.
3. Place Tape No. 812 in reader.
4. Check to ensure that the Rim Loader is in memory. This procedure is outlined in Section 15-3.
5. Set teletype to on-line.
6. Set switch register to 7756; press Load Address key, then Start key.
7. Turn on reader.
8. After program has been read in, turn off reader and remove tape, set switch register to 0020.
9. Turn punch on.
10. Press Load Address key.
11. SW1 should be down. Press Start key.
12. Examine leader while it is being generated - Spacing of holes should be regular and no odd shaped holes apparent. If not, halt test by pressing Stop key.
13. When a sufficient amount of leader has been punched ($2\frac{1}{2}$ to 3 feet), place the free end of the tape in the reader. Do not tear tape off from punch.
14. Turn reader on and set SW1 key in up position.
15. Punch and print-out will operate continuously until an error occurs or until the Stop switch on the computer is depressed.
16. If punch and reader stop while the leader is in the reader, the reader has erred by missing a hole in the leader and the missed hole will show up as an unlit light in the accumulator. Discontinue test.
17. If test stops when the content of the Memory Address is 0050 or 0052 the interrupt is not working properly and test is discontinued.
18. If test stops when the content of the Memory Address is 0074 the character read from tape is not what is should have been. The Accumulator lights display the character read. Record the content of the Accumulator lights and press the Continue key to reach next halt in test.
19. Computer will stop immediately after Continue Key is pressed with the correct content for the previous halt in the Accumulator lights.
20. If the previous halts occurred when the contents of the Memory Address lights were 0074 and 0077, respectively, the test should be continued to see if the error will reoccur.

21. To restart the test, turn off the reader and remove tape. Set switch SW1 down and press the Continue key. Repeat items 13 and 14 of the procedure. If error reoccurs, discontinue the test.
22. If none of the errors listed in items 16 through 19 occur, stop the test after 15 seconds by pressing the Stop key on the computer.

Analysis

If the hole spacing is irregular or there is visual evidence of over-lapping of punched holes, then the tape drive mechanism is faulty. Call the teletype repairman.

If any error induced halt occurred during the test, the contents of the Memory Address (MA) lights and of the Accumulator (AC) lights should be recorded and the test continued or discontinued as per instructions in the Test Procedure. Call a computer field service engineer and show him the test results.

The following conditions serve to locate the source of computer malfunction.

Contents of Memory Address	Cause of Error
0050	Input from reader did not cause an interrupt. Possible difficulties: incorrect execution of ION, no signal from reader, trouble in the interrupt system.
0052	The interrupt occurred before the instructions following the ION were executed. Probable trouble in the interrupt system.
0074	The character read from the tape is not what it should have been. The accumulator displays the incorrect character.
0077	The AC lights display the correct character for the previous (0074) halt. Compare with the character found in the accumulator from the previous halt to determine whether information was dropped or added in punching.

15.10 On-Line Teletype Keyboard/Printer Test

This is a two part test. In the first part, the computer is programmed such that the teletype will immediately print any character typed on the teletype keyboard. This, of course, will not hold true for any of the "outlawed characters" listed in the previous Off-Line Keyboard Test.(Section 15-8) These characters are non-printing as they are instructions to the teletype and/or the computer. For instance, carriage return instructs the teletype to shift to the beginning of a line and line feed instructs the teletype to advance the paper, operations that are normally performed manually on an ordinary typewriter.

The second part of the test consists of the teletype printing a line of characters and repeating this line until an error is encountered or until the test is halted by pressing the Stop key. The illustration at the end of the section shows several examples of the line of characters that will be printed during this part of the test. What may not be readily apparent is that each line does not start with an exclamation mark, but rather with a space.

The tape to be used in this test is Tape No. 814: On-Line Teleprinter Test.

Procedure

1. Turn on computer - teletype punch and reader should be off.

2. Turn teletype to line (on-line).

3. Place Tape No. 814 (Maintenance: On-Line Teleprinter Test) in the reader.

4. Set Switch Register keys to 7756.

5. Press Load Address Key.

6. Press Start Key.

7. Turn Reader on.

8. When loading is complete, turn Reader off and remove tape.

9. Set Switch Register keys to 0020.

10. Press Load Address Key.

11. Set SW1 in the up position (Position of other Switch Register keys is immaterial).

12. Press Start Key.

13. Type any character except the "outlawed" characters any number of times. The printer should print out the same characters as the key struck. If not, note the key struck and the letter typed out.

    For example, if the D key is struck and E is printed; repeat the test by striking the D key again and then the E key and record how often the error occurs.

14. Type return, then line feed. Although these are "outlawed" they are used here to reset the carriage and advance the paper to a clean line.

15. Set the SW1 key down. Again, the position of other keys in the switch register is immaterial.

16. Type any "outlawed" character that is identified with an asterisk on page 47. The printer will proceed to type out a line of characters beginning with a space. This line (always beginning with a space) will be repeated until an error occurs or until the Stop key is depressed. If no error occurs, generate 4 to 6 lines of print and then press the Stop key.

Analysis

If errors are found when the individual characters are tested, (item 13 under procedure) the nature and frequency of these errors should be recorded. If the Off-Line Keyboard Test revealed no errors then there exists a computer malfunction. Call a field service engineer.

For the second part of this test, (items 14 through 16 under procedure) the types of errors are limited. When an error induced halt does occur, information as to the nature of the error is displayed in the Program Counter lights. The contents of the Program Counter should be recorded and the test continued or discontinued as per the following instructions:

Contents of Program Counter	Instructions	Source of Error
0023	(Record contents and press	Computer-Call Fld. Serv.Engr.
0026	(Continue Key-Check	
0033	(frequency of error	
0051	(	
0073	(Discontinues test	Computer-Call Fld. Serv.Engr.
0003	(	
0113	Press Continue Key	Teletype-Call Teletype Rep.Man

It is possible that errors will occur in the typed sheet which will not cause the test to stop. Therefore, after several lines of type have been generated, stop the test by pressing the Stop key and check the typed sheet for errors. If an error is found, preserve the typed sheet and call the field service engineer.

The following table lists suggested causes for the types of errors found by this test. These will be of interest to the field service engineer or teletype repairmen. Therefore, should an error be detected by this test, show him not only the test results, but also the following diagnostics:

Contents of Program Counter	Causes
0023	The KCC instruction failed to clear the Accumulator. Indicates that clear pulses were not sent to the Accumulator and/or the input flag flip-flop.
0026	The KCC instruction failed to clear the keyboard flag. Less likely, the KSF instruction skipped with the flag cleared. Indicates that clear pulses were not sent to the Accumulator and/or the input flag flip-flop.
0033	A zero character has been received. The KRB instruction failed to transmit the contents of the keyboard buffer to the Accumulator after clearing the latter. It is also possible that the buffer was clear, in which case the failure was in the transmission lines between keyboard and buffer.

Contents of Program Counter	Causes
0051	The TLS instruction failed to set the printer flag. Less likely, the flag was set, but the TSF instruction failed to skip.
0073	When the interrupt was enabled after the TLS had been executed, an interrupt should have occurred. Either the printer line to the interrupt system or the interrupt system itself is in error.
0003	Interrupt occurred too soon. This indicates that the CLA was not executed; the interrupt system is at fault. Normally, if a program interrupt is waiting when the ION instruction is executed, the interrupt will not be serviced until the instruction following the ION has been executed. In this test program, this instruction is a CLA. The test leading to this half is an SNA. If the CLA had been executed, the skip would not have occurred.
0113	An input flag was set after the WRU character was typed. Printers normally are modified so that receipt of a WRU will not cause a response to set input flag. Check ANSWER-BACK drum in Teletype for proper modification.

Typical examples of the line of characters generated in the second part of the On-Line Teletype Keyboard/Printer Test.

```
!"#$%&'()*+,-./Ø123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]↑←
!"#$%&'()*+,-./Ø123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]↑←
!"#$%&'()*+,-./Ø123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]↑←
!"#$%&'()*+,-./Ø123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]↑←
!"#$%&'()*+,-./Ø123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]↑←
! (Stopped by pressing Stop key on computer)
```

15.11 On-Line Teletype Reader Test

The main purpose of this test is to check the performance of the reader and the transmission lines between the reader, its buffer and the accumulator (AC). Secondarily, it can be used as a quick check of the tape advance mechanism. If the holes in the tape show irregular spacing, overlapping or enlargement after passing through the reader there may be some mechanical malfunction in the reader or punch.

The test consists of having the reader continuously scan a specially prepared tape and checking the output from the reader for accurate transmission to the AC. A dropped bit (a hole missed) or an added bit (a hole read where there was none) will cause the program to halt with the erroneous characters appearing in the AC lights.

The special tape mentioned above is produced as part of the test and is made up of two codes; 000 (no holes punched) or 377 (all holes punched across the width of the tape). These are arranged in alternating groups of no holes (blanks) or all holes. Each group of blanks is paired to a group of holes.

The test program has the computer count the number of lines of blanks in one group and subtract from it the number of lines of holes in the succeeding group. Should the count not be equal to zero after paired groups of blanks and holes are read, the test automatically stops. Therefore, error induced halts will occur whenever a bit is added or dropped or when a line of characters (blanks or holes) is missed.

Procedure

1. Turn on computer.

2. Turn teletype to line (on-line); reader and punch should be off.

3. Check to see if Rim Loader is in memory. This procedure is outlined in Section 15-3.

4. Place Tape No. 810, On Line Teletype Reader Test, in the reader.

5. Set switch register to 7756.

6. Press Load Address key on computer.

7. Press Start key on computer.

8. Turn reader on.

9. When reader is finished scanning tape, turn reader off and remove the tape.

10. Turn teletype to local (off-line)

11. Turn punch on.

12. Press and hold these keys on the teletype; control, shift and repeat. Lastly, press and hold the P. key. The punch will now operate and allow it to generate about six inches of tape (this is the "leader" for this test tape). Release the P. key first, then the other three keys. Turn punch off.

13. Turn teletype to line.

14. Set Switch Register to 0100.

15. Turn punch on.

16. Press Load Address key.

17. Press Start key.

18. Allow the punch to generate about 2 to 3 feet of tape, then press the Stop key on the computer, turn punch off and tear off tape.

19. Place the leader of this new tape in the reader.

20. Set Switch Register to 0001.

21. Press Load Address key.

22. Press Start key.

23. Turn reader on.

24. Important - If no errors appear which cause the test to stop, then press the Stop key on computer before the reader scans all of the tape.

Analysis

If an error occurs and the test is stopped, record both the contents of the Memory Address and of the Accumulator registers. If only a few inches of tape remain to be read, do not continue the test. With one foot or more of tape not read, the test is continued by pressing the Continue key on the computer. In all cases, however, the test is to be discontinued before all of the tape clears the reader.

Any errors discovered by this test are computer errors provided that all of the off-line tests run before this test revealed no errors. Call the field service engineer. Show him the test results and the following list which indicates possible reasons for errors.

Contents of Memory Address	Cause of Error
0025	The last character read was incorrect. The AC contains the erroneous code. Repeat test.
0055	Character count is incorrect. The program has just read a group of 377 codes and the number of characters in this group is not identical to the number in the preceding group of 000 codes. The number in the AC is the difference between the counts. The error was probably the result of a missed character or a failure in transmission of a pulse from the reader buffer to the AC.

15.12 Digital Interface Equipment Test

This sequence of tests checks the interface equipment special to the billet analysis system. In addition to the Rim Loader being in memory the Bin Loader must also be in memory.

Procedure

1. Turn computer on

2. Turn teletype to line (on-line) reader and punch should be off

3. Check to see if Rim Loader is in memory. This procedure is outlined in Section 15.3.

4. Place Tape No. 1, Bin Loader, in the reader.

5. Set Switch Register keys to 7756

6. Press Load Address key on computer

7. Press Start key on computer

8. Turn reader on

9. After reader has scanned tape, turn reader off and remove tape

10. Set Switch Register keys to 7777

11. Place Tape No. 5, Interface Checkout, in the reader

12. Press Load Address key

13. Press Start key

14. Turn on reader (Mid-point or end halt of tape with 7402 in memory buffer).

15. After reader has scanned tape, turn reader off and remove tape

16. Set Switch Register keys to 0200

17. Press Load Address key. Press Start. Computer will halt with 7402 in the Memory Buffer lights.

18. Set Switch Register keys to 4000

19. Turn on main power switch to Ultrasonic Station if not already on

20. Press Continue-An I should be printed and the computer will halt with 7402 in Memory Buffer lights

21. Set Switch Register keys to 2000

22. Press Continue key

23. LC? will be printed and the busy lamp should light. If lamp lights, type an exclamation point ! to acknowledge this. If lamp does not light, type any "outlawed" character. Test will be discontinued at this point if unsuccessful.

24. If test is successful, computer will stop with 7402 in memory buffer lights and LO? will be typed on a new line. Again type exclamation point ! to acknowledge successful print-out.

25. Set Switch Register keys to 1000.

26. Press Continue key.

27. AC? will be printed and the alarm will sound. If alarm sounds, type ! otherwise type any "outlawed" character. Assuming that the alarm rang, AO?, will be typed on a new line. Press the alarm reset button on the interface panel. If the alarm shuts off, again type !. If not, then type any "outlawed"character and discontinue the test. Assuming that the alarm did cease and a ! was typed, the computer will halt with 7402 in the Memory Buffer Lights

28. Set Switch Register keys to 0400

29. Close occupancy contacts (manual control on digital interface panel). Press Continue. If contacts are closed, an 0 will be printed on a new line. If the tests were done in the sequence outlined above and all were successful, an OK! is typed on a new line by the computer and the test is ended.

Analysis

Should any of the tests disclose an interface malfunction, discontinue the tests, press Stop key on computer and call a field service engineer.

15.13 On-Line Instruction Test

This test is a check on three basic computer operations or functions plus a simple test of the teletype printer. In the first part of the test the computer will halt three times. The first time when the contents of the Memory Address (MA) lights are 0200, the second time when the MA lights show 0202 and the third when 0205 is the contents of the M A lights. These are not error induced halts, but are programmed stops. After these stops are made, the computer should operate continuously unless it is stopped by pressing the Stop key or by an error induced stop.

A simple check on the teletype printer is included in the second part of the test after the three automatic stops. The printer will print out ?@? as a keyboard printer test. A 1 printed directly under the first question mark will show test completion. After this printer test has been performed once or twice the teletype may be turned off.

This test is different from all other on-line maintenance tests in that the computer must be slightly modified before the test can be executed. This modification is discussed in detail in the procedure.

Procedure

1. Computer and teletype should be off. Using the same key that fits the panel lock and power lock, open the computer proper. This is done by placing the key in the lock on top of the computer and giving it a quarter turn clockwise. Swing out the left hand side of the computer. There will be one lead on this side of the computer which is not connected. Remove the temporary tape insulating the terminal on this lead, and place this terminal on MF 36, pin S. MF is the bottommost tier and is so identified. MF 36, pin S, is two pins from the extreme right and the second pin from the bottom. To close the computer hold both sides tightly against the center frame (use elbows for this) and turn key 1/4 turn counterclockwise. Remember, this lead must be removed at the completion of this test.

2. Turn computer on

3. Turn teletype to line (on-line). Reader and punch should be off

4. Place Tape No. 701-1, On-Line Instruction Test, in the reader

5. Check to see that the Rim Loader is in memory. This procedure is in Section 15-3.

6. Set Switch Register keys to 7756

7. Press Load Address key on computer

8. Press Start key on computer

9. Turn on reader

10. After reader finishes scanning the tape, turn it off and remove the tape

11. Set Switch Register keys to 0200

12. Press Load Address key

13. Set Switch Register keys to 7777

14. Press Start key

15. Computer will halt with 7402 in the Memory Buffer lights and 0200 in Memory Address lights. This is a programmed halt and not an error. Press Continue key on Computer

16. Computer will halt with 7402 in the Memory Buffer lights and 0202 in the Memory Address lights. This is a programmed halt. Press Continue key on computer

17. Computer will halt with 7402 in the Memory Buffer lights and 0205 in the Memory Address lights. If any one of these listed stops fail to occur, or differed in Memory Buffer or Memory Address content with that listed above, there is a computer error. If all three stops do occur, and in the sequence given above, then press the Continue key on the computer.

18. At this point, if no error occurs, the computer will instruct the teletype to print out the following:

    ?@?

    1

    If the above print out does not occur, record the contents of the Memory Address lights.

19. It is desirable to verify the results by a second check. Restart the program by pressing the Continue key.

20. It is normal practice to turn off the teletype after one or two ? @ ? and 1 have been printed.

21. Remember that the lead must now be disconnected from MF 36, pin S. (Turn computer power off).

Analysis

Should any of the three programmed stops not occur, or if the contents of the Memory Address and Buffer lights differ from those specified, the computer is in need of repair.

The following remarks will be of benefit only to the field service engineer.

This is a minimal test of memory reference instructions, operating instructions, interrupt mode and keyboard printer. It is not intended to be diagnostic in nature and rests on a comparison of a test pattern with the results of an operation. An invalid comparison causes a test halt. The type of error is found by reading the Memory Address register and comparing its content to the following list. The instruction code (3 Letters) indicates the faulty instruction.

0200, 0202, and 0205 (all octal) are the only visual inspection halts.

C(MA)	CODE	TYPE
0200	hlt	test
0202	osr	test
0205	cla	test
0207	skp	test
0212	sma	test
0216	sma	test
0221	spa	test
0225	spa	test
0230	sza	test
0234	sza	test
0237	sna	test
0243	sna	test
0245	szl	test
0251	stl	test
0260	cll	test
0264	snl	test
0270	dml	test
0274	cml	test
0300	cma	test
0304	iac	test
0311	cma	test
0316	sta	test
0322	cia	test
0326	link	test
0335	and	test
0341	and	test
0347	and	test
0353	and	test
0357	tad	test
0364	tad	test
0404	tad	test
0413	tad	test
0417	tad	test
0423	dca	test
0427	dca	test
0436	dca	test
0254	snl	test
0442	isz	test
0447	osz	test
0453	jmp	test
0460	jms	test
0464	jms	test
0472	jms	test
0504	jms	test
0513	and	indirect addressing test
0517	jmp	indirect addressing test

C(MA)	CODE	TYPE
0524	jms	Indirect addressing test
0531	and	page zero addressing test
0533	jmp	page zero addressing test
0540	and	indirect page zero addressing test
0544	ral	test
0552	ral	test
0554	ral	test
0563	ral	test
0605	ral	test
0611	rtl	test
0617	rtl	test
0624	rtl	test
0630	rtl	test
0636	rar	test
0644	rar	test
0651	rar	test
0655	rar	test
0663	rtr	test
0671	rtr	test
0676	rtr	test
0702	rtr	test
0720	auto indexing test	

15.14 On-Line Memory Address Test

This program provides a crude inspection of the Memory Address register's performance and of the decoder network which selects a given memory cell.

A quantity equal to the address of a particular memory cell is deposited in that cell. The cell contents are then read by the computer and if this operation is successful the procedure is repeated using the next cell in sequence.

When all of the testable memory has been checked in this manner, the computer returns to the first cell tested and reads that cell and each succeeding cell. It then repeats the first test. In essence the computer scans the testable section of its memory by alternating deposit and read, and read only tests.

If an error occurs in any of the individual deposit and read tests, or in the read only tests, the computer is stopped and the lights of the Memory Address and Accumulator display information about the nature of the error. It is important that the test be continued after an error to determine if other errors are associated with it. The computer will operate continuously if no errors occur.

Procedure

1. Turn on computer
2. Turn teletype to line (on-line). Reader and punch should be off
3. Place Tape No. 803, On Line Address Test, in the reader
4. Check to see that Rim Loader is in memory. This procedure is outlined in Section 15.3.
5. Set Switch Register keys to 7756
6. Press Load Address key on computer
7. Press Start key on computer
8. Turn reader on
9. When reader is finished, turn reader off and remove tape from reader
10. Set Switch Register keys to 0001
11. Press Load Address key on computer
12. Press Start key on computer
13. Computer will operate continuously until stopped by an error or by pressing the Stop key on computer
14. If an error induced halt occurs, record the contents of the Memory Address lights and of the Accumulator lights
15. Press Continue key. See if error repeats itself. If so, call field service engineer.

16. If no error induced halt occurs after 30 seconds, stop test by pressing Stop key on computer.

Analysis

The following remarks will be helpful to the field service engineer in his diagnosis.

In general, this test will be sensitive to two types of difficulty in the selection network. If a selection line is open at one point, the memory registers selectable by that line are effectively isolated from the central processor. The program will be unable to write information into those cells or read information out. Conversely, if two lines are shorted together then information entering or leaving the registers selectable by one line will also enter or leave those selectable by the other. Thus, the same information will appear in two different registers.

The following list indicates errors which can cause a test halt. The listing of error induced halts furnished to the field service engineer should contain the 0017 then 0022 contents of the memory address. If not, the field service engineer should repeat the test.

Memory Address Contents	Cause of Errors
0017	Contents of the memory cell just inspected were incorrect. The AC displays actual contents
0022	The AC displays the address of the cell causing the previous error.

15.15 On-Line Checkerboard Test

This set of instructions tests the computer memory under the worst possible operating conditions (marginal voltages). This is a two part test with part one called the High Checkerboard Test and part two, the Low Checkerboard Test. Both parts of the test require the presence of the RIM Loader in memory, but the Low Checkerboard is run last as it destroys the RIM Loader during the course of the test. Therefore, the operator must place the Rim Loader back into the computer memory (via the Switch Register Keys) upon the completion of the test.

Procedure

1. Turn computer on

2. Turn teletype to line (on-line). Reader and punch should be off

3. Check to see if Rim Loader is in memory. This procedure is outlined in Section 15-3.

4. Place Tape No. 802, Checkerboard -- High, in the reader

5. Set Switch Register keys to 7756

6. Press Load Address key

7. Press Start key

8. Turn reader on

9. When reader has finished scanning tape, turn reader off and remove tape

10. Set Switch Register keys to 7450

11. Press Load Address key

12. Set Switch Register keys to 0100

13. Press Start key

14. The computer will operate continuously until an error is detected or the Stop key is pressed. If no error induced halt occurs after 30 seconds press Stop key

15. If an error induced halt occurs, record the contents of the Memory Address lights and of the Accumulator lights. Press the Continue key on the computer. The next stop will give additional information about the previous error. Record the contents of the Memory Address Lights and of the Accumulator Lights. Press the Continue key on the computer to see if any other errors can be detected

16. After the test has run to operator satisfaction, the operator should discontinue the test by pressing the Stop key on the computer.

17. The second part of this test, the Low Checker Board Test, is run in an identical way save for the following exceptions:

    (i) item 3 is unnecessary

    (ii) for item 4, the tape to be placed in the reader is Tape No. 802, Checkerboard -- Low

    (iii) in item 10 change Switch Register setting to 0001

18. Remember after completion of Checkerboard -- Low Test, the Rim Loader has to be replaced in computer memory.

Analysis

If error induced halts occur, record the contents of the Memory Address lights and of the Accumulator lights. After pressing the continue key, the next halt gives information about the previous stop. Pressing the continue key after the second halt restarts the program. If malfunctions are found by these tests, call the field engineer.

There are two versions of this test. The low End program occupies registers 0003-0111 and tests memory from 0112-7777. The High End program occupies registers 7450-7555 and tests memory from 0000-7447.

The following lists indicate expected error stops for the High and also the Low Checkerboard test.

Content of Memory Address	Cause of Error - High Checkerboard Test
7536	The contents of a given memory cell should be either 7777 or 0000. An error occurs if a 1 becomes a zero or vice-versa. The memory cell does not contain 7777 or 0000. The AC displays contents of cell in error.
7541	AC contains address of cell causing previous error stop.

Content of Memory Address	Cause of Error - Low Checkerboard Test
0071	Identical to 7536 for High End Test
0074	Identical to 7541 for High End Test

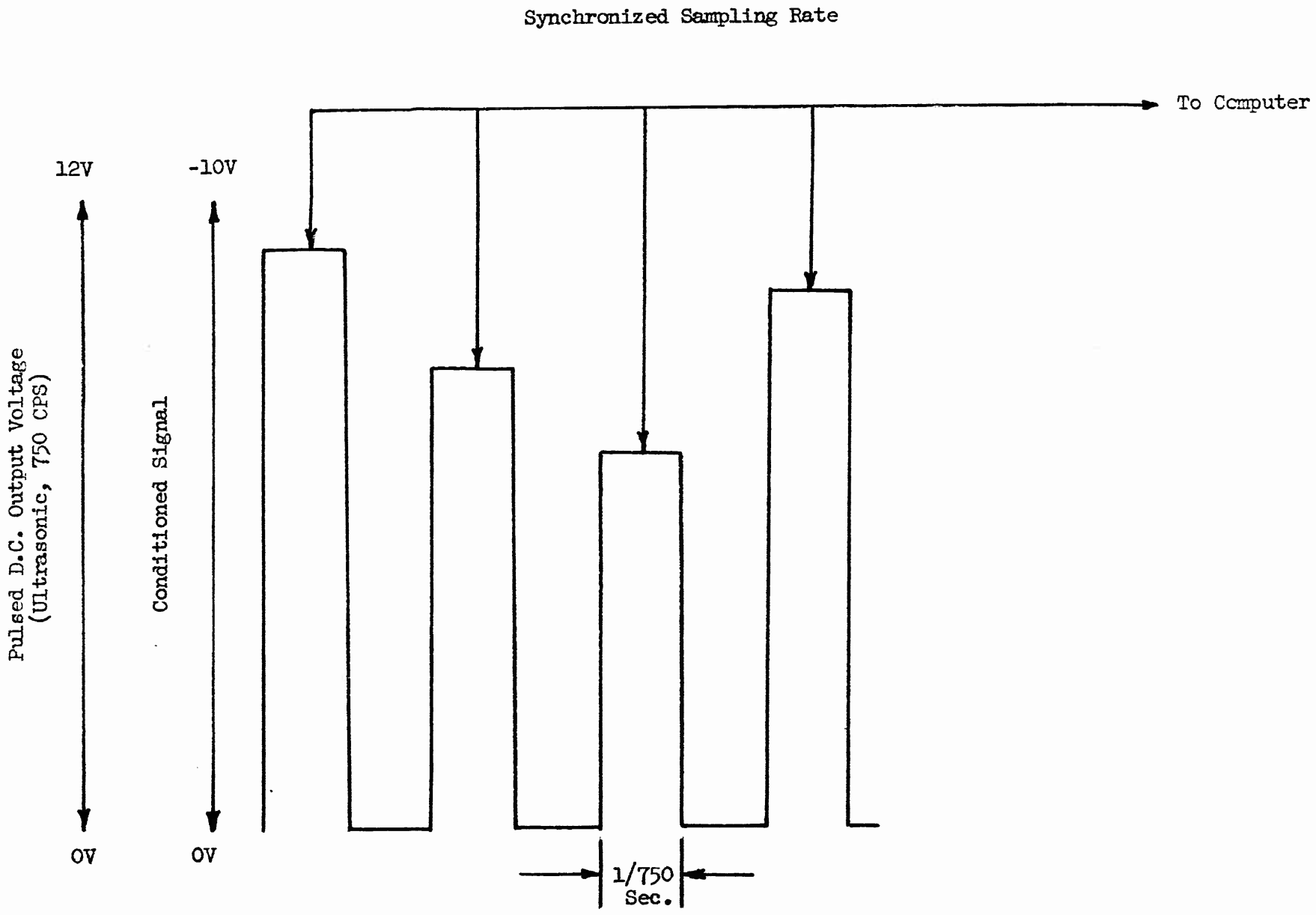


Figure 1 - Sampling of Random Voltage Signals

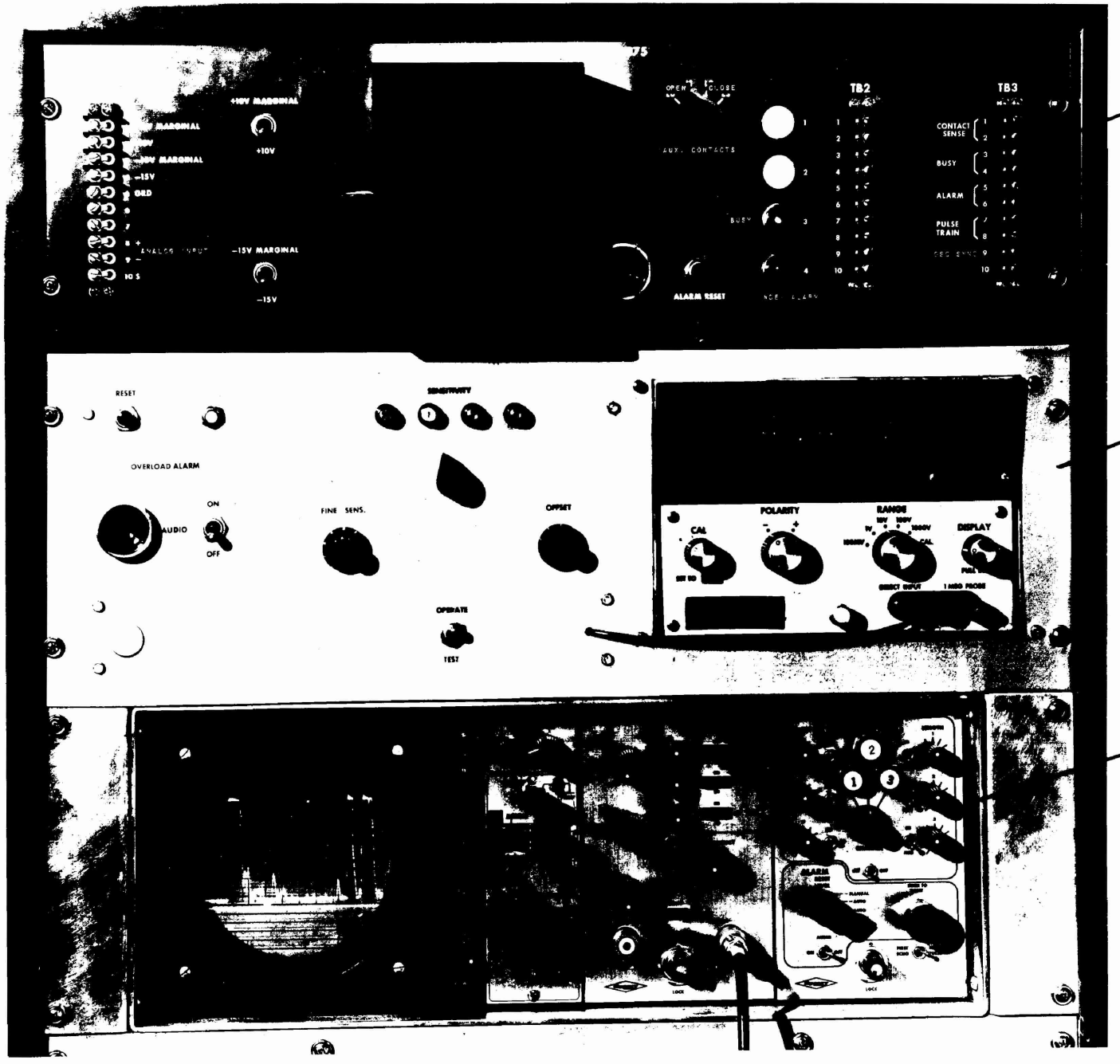


FIGURE 2 - ULTRASONIC STATION

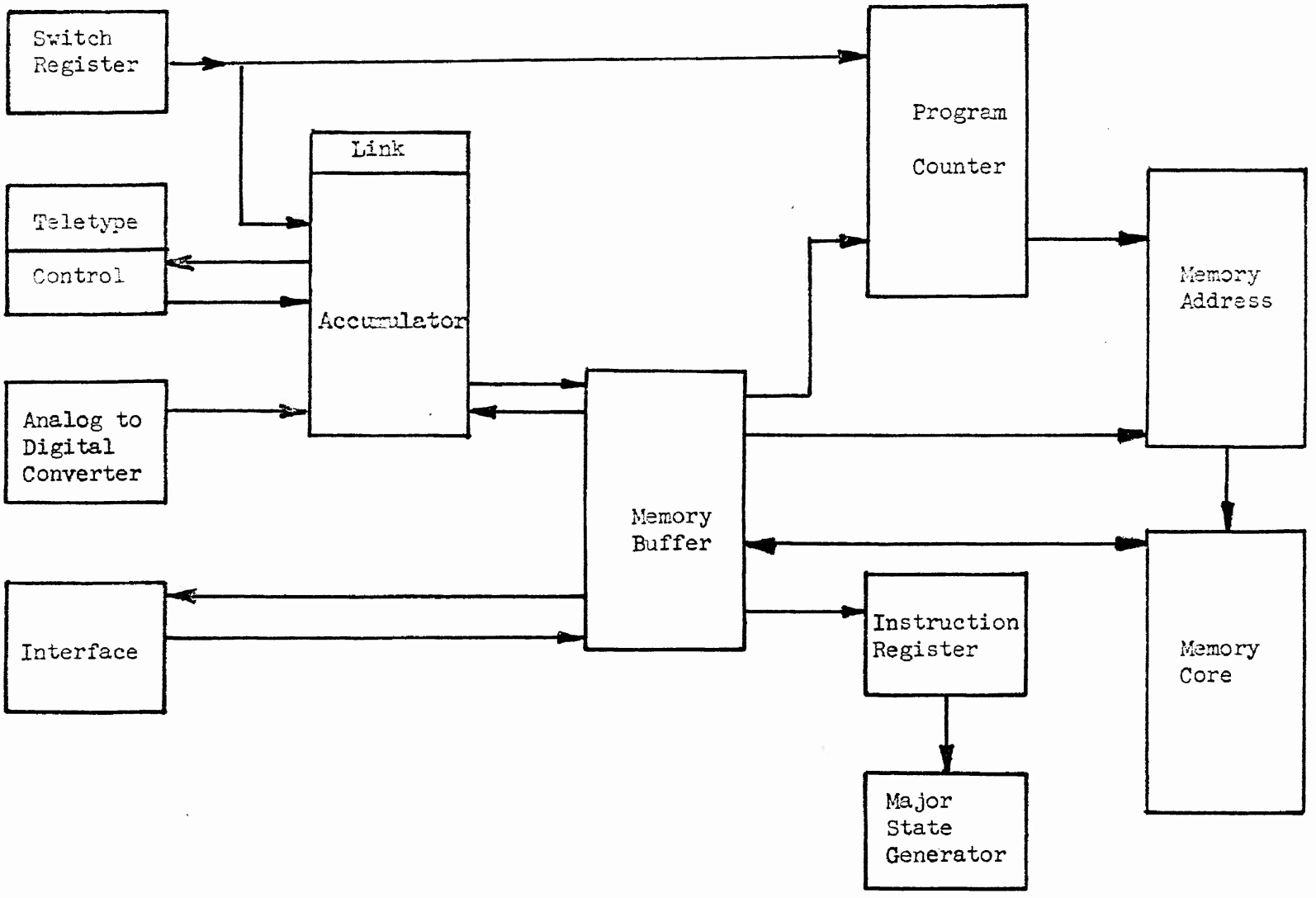


FIGURE 3 - Information Flow Between Various Computer Registers

C4
C4
C4
C4
C7
C7
C7
C7
C13
C13
C13
C13

FIGURE 6 - Calibrate 0 Mode Report

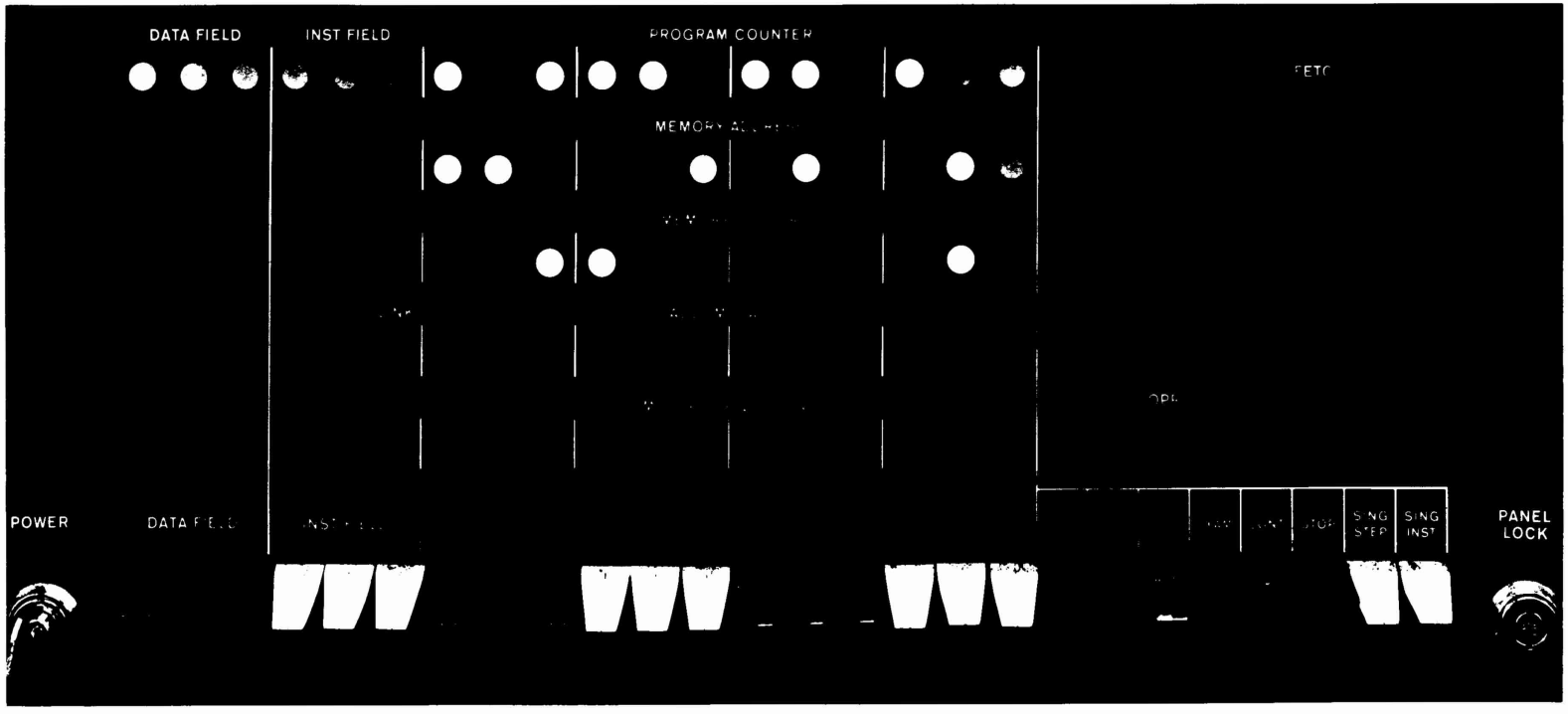


FIGURE 4 - COMPUTER CONSOLE PANEL CONTROLS

CALIBRATE 2
ULTRASONICS AND COMPUTER SYSTEM
DATE
OPERATOR
STAND. REF. BLK.
SENSITIVITY CONTROL
REF. SIGNAL HEIGHT
GAIN SETTING

CATEG	COUNT	FREQ
1		.0000
2		.0000
3		.0000
4		.0000
5		.0000
6		.0000
7		.0000
8		.0000
9		.0000
10		.0000
11		.0000
12		.0000
13		.0000
14		.0000
15		.0000
16	1546	1.0000

FIGURE 8 - Calibrate 2 Mode Format

HEAT OPERATOR

BILLET DATE

COUPON

PASS

GATE

GAIN SETTING P. FACT SET # 1.0

CATEG	COUNT	FREQ	P. FACT.	PROD
1	97	.0246	.5	.0123
2	842	.2132	1.0	.2132
3	967	.2449	2.0	.4897
4	656	.1661	4.0	.6645
5	378	.0957	8.0	.7658
6	308	.0780	16.0	1.2479
7	289	.0732	32.0	2.3419
8	172	.0436	64.0	2.7875
9	101	.0256	128.0	3.2737
10	75	.0190	256.0	4.8620
11	33	.0084	512.0	4.2785
12	11	.0028	1024.0	2.8524
13	9	.0023	2048.0	4.6675
14	5	.0013	4096.0	5.1861
15	4	.0010	8192.0	8.2978
16	2	.0005	16384.0	8.2978

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FIGURE 5 - Billet Analysis Report Format

CATEG	COUNT	FREQ
1	422	.1076
2	1351	.3444
3	796	.2029
4	456	.1162
5	351	.0895
6	286	.0729
7	136	.0347
8	65	.0166
9	29	.0074
10	11	.0028
11	8	.0020
12	7	.0018
13	1	.0003
14	3	.0008
15	1	.0003
16		.0000

FIGURE 10 - Short Form Report Format

CALIBRATE 1
A/D AND COMPUTER SYSTEM
DATE
OPERATOR
D.C. VOLTS

CATEG	COUNT	FREQ
1		.0000
2		.0000
3		.0000
4		.0000
5		.0000
6		.0000
7		.0000
8		.0000
9		.0000
10		.0000
11		.0000
12		.0000
13	1857	1.0000
14		.0000
15		.0000
16		.0000

FIGURE 7 - Calibrate 1 Mode Format

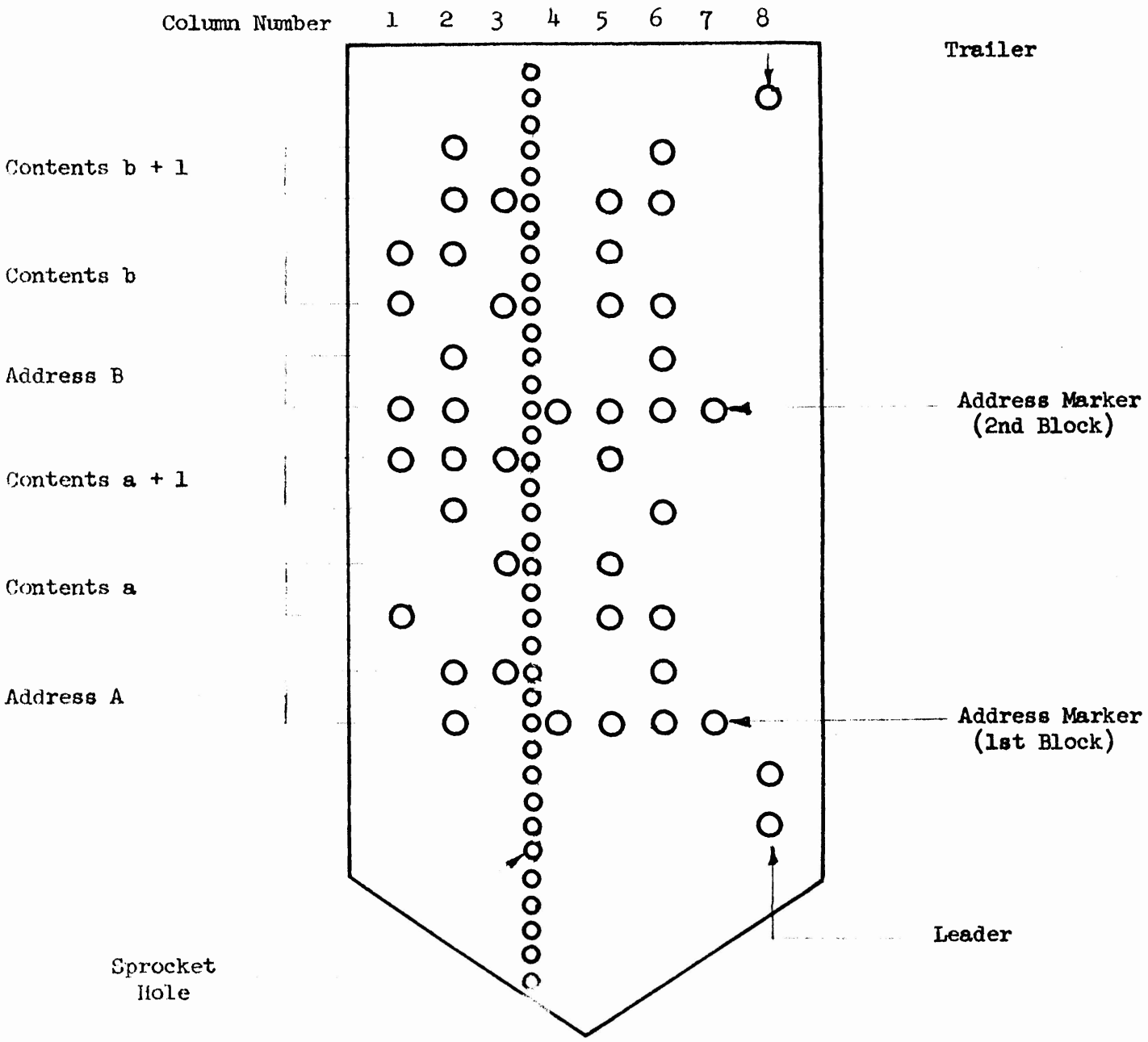


Figure 12 - BIN Format Tape

SET #1	SET #2	SET #3	SET #4
.5	1.0	1.0	1.0
1.0	11.0	51.0	101.0
2.0	31.0	151.0	301.0
4.0	61.0	301.0	601.0
8.0	101.0	501.0	1001.0
16.0	151.0	751.0	1501.0
32.0	211.0	1051.0	2101.0
64.0	281.0	1401.0	2801.0
128.0	361.0	1801.0	3601.0
256.0	451.0	2251.0	4501.0
512.0	551.0	2751.0	5501.0
1024.0	661.0	3301.0	6601.0
2048.0	781.0	3901.0	7801.0
4096.0	911.0	4551.0	9101.0
8192.0	1051.0	5251.0	10501.0
16384.0	1201.0	6001.0	12001.0

FIGURE 9 - Progression Factors for Sets 1 Through 4 (These Sets are Automatically Entered in Core Memory When the Billet Analysis Program Tape is Loaded).

	SURFACE NUMBER	SEVERITY	
	1	Not Inspected	
	2	Not Inspected	
	3	Not Inspected	
	4	Not Inspected	
	5	Not Inspected	
Gate 1	6	0.00	
	7	0.02	
	8	0.00	
	9	0.00	
	10	0.00	
	11	0.00	
	12	0.00	
	13	0.00	
	14	0.00	
	15	0.00	
	16	0.00	
Gate 2	17	0.00	
	18	0.00	
	19	0.00	
	20	0.00	
	21	0.00	
	22	0.00	
	23	0.00	
	24	0.00	
	25	0.00	
	26	0.00	Average Magnetic Particle
	27	0.00	Rating = 0.0045
Gate 3	28	0.00	
	29	0.02	Ultrasonic Index = 2.9
	30	0.02	
	31	0.01	
	32	0.00	
	33	0.00	
	34	0.00	
	35	0.01	
	36	0.01	
	37	0.00	
	38	0.00	
Gate 4	39	0.00	
	40	0.00	
	41	0.01	
	42	0.01	
	43	0.00	
	44	0.00	
	45	0.00	
	46	0.00	
	47	0.00	
	48	0.04	
	49	0.00	
Gate 5	50	0.07	
	51	0.06	
	52	0.01	
	53	0.03	
	54	0.03	
	55	0.01	

Figure 15 - Magnetic Particle Rating of Electric Furnace Vacuum Degassed Coupon 2C

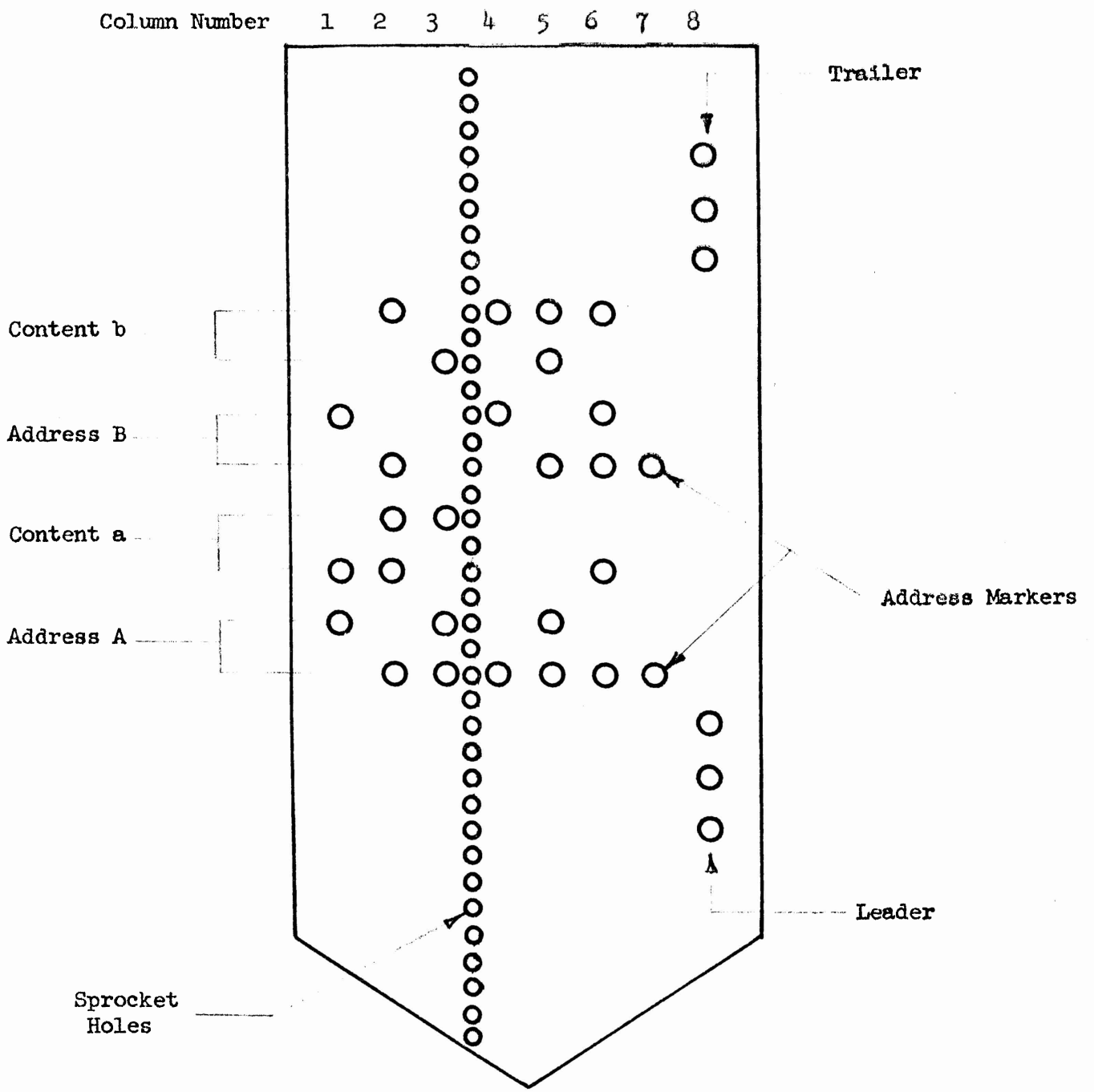


Figure 11 - Rim Format Tape

	SURFACE NUMBER	SEVERITY	
	1	Not Inspected	
	2	Not Inspected	
	3	Not Inspected	
	4	Not Inspected	
	5	Not Inspected	
Gate 1	6	0.00	
	7	0.00	
	8	0.00	
	9	0.00	
	10	0.00	
	11	0.00	
	12	0.00	
	13	0.00	
	14	0.00	
	15	0.00	
	16	0.00	
Gate 2	17	0.00	
	18	0.00	
	19	0.00	
	20	0.00	
	21	0.00	
	22	0.00	
	23	0.00	
	24	0.00	
	25	0.12	
	26	0.10	Average Magnetic Particle
	27	0.01	Rating = 0.12
Gate 3	28	0.00	
	29	0.26	Ultrasonic Index = 3.9
	30	0.20	
	31	0.48	
	32	0.06	
	33	0.12	
	34	0.00	
	35	0.00	
	36	0.00	
	37	0.00	
	38	0.00	
Gate 4	39	0.00	
	40	0.00	
	41	0.00	
	42	0.01	
	43	0.00	
	44	0.01	
	45	0.01	
	46	0.00	
	47	0.00	
	48	0.00	
	49	0.00	
Gate 5	50	0.00	
	51	Not Inspected	
	52	Not Inspected	
	53	Not Inspected	
	54	Not Inspected	
	55	Not Inspected	

Figure 17 - Magnetic Particle Rating of Open Hearth Coupon 3G

FIGURE 13 - TELETYPE STATION

ELECTRIC FURNACE VACUUM DEGASSED 2C

CATEGORY	COUNT	FREQUENCY	P. FACTOR	PRODUCT
1	12,111	.0988	.5	.0494
2	51,318	.4186	1	.4186
3	31,832	.2597	2	.5194
4	15,619	.1274	4	.5096
5	7,360	.0600	8	.4800
6	2,828	.0231	16	.3696
7	1,113	.0091	32	.2912
8	335	.0027	64	.1728
9	64	.0005	128	.0640
10	6	.0001	256	.0256
11	0	-	-	-
12	0	-	-	-
13	0	-	-	-
14	0	-	-	-
15	0	-	-	-
16	0	-	-	-

Calculated Index - 2.9

Figure 19 - Ultrasonic rating determined from cumulative counts that occurred for eighty-one scans (0.050" apart) in center gate.

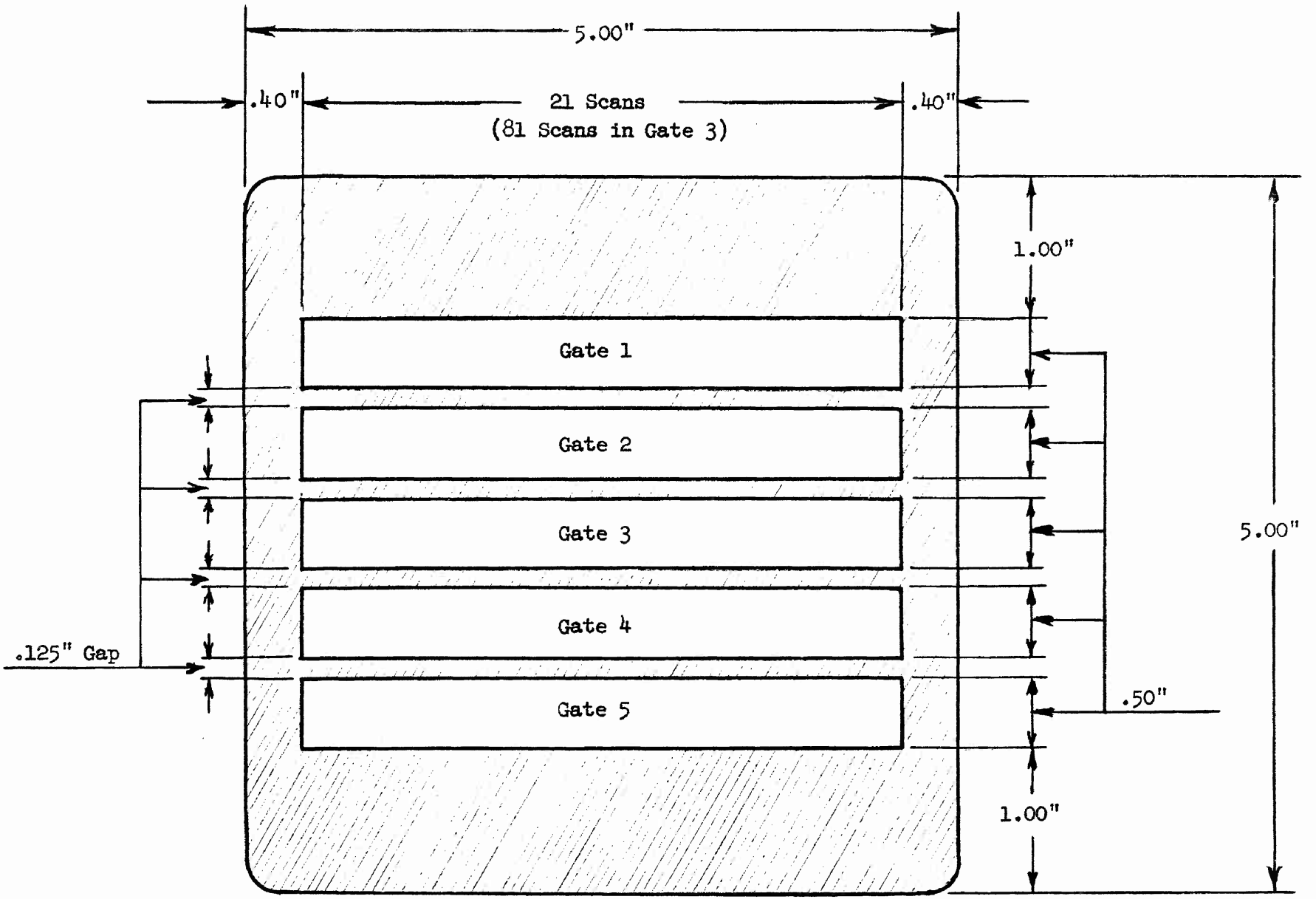


Figure 14 - Gated Areas of Ultrasonic Inspection with 5 Inch Round Corner Square Billets for Magnetic Particle Inspection Correlation Study

OPEN HEARTH 3G

CATEGORY	COUNT	FREQUENCY	P. FACTOR	PRODUCT
1	30,744	.2516	.5	.1258
2	50,329	.4119	1	.4119
3	24,176	.1979	2	.3958
4	10,757	.0880	4	.3520
5	3,847	.0315	8	.2520
6	1,389	.0114	16	.1824
7	564	.0046	32	.1474
8	200	.0016	64	.1024
9	66	.0005	128	.0640
10	38	.0003	256	.0768
11	24	.0002	512	.1024
12	8	.0001	1024	.1024
13	11	.0001	2048	.2048
14	12	.0001	4096	.4096
15	3	.00002	8192	0.1638
16	6	.00005	16384	0.8192

Calculated Index - 3.9

Figure 21 - Ultrasonic rating determined from cumulative counts that occurred for eighty-one scans (0.050" apart) in center gate.

	SURFACE NUMBER	SEVERITY	
	1	Not Inspected	
	2	Not Inspected	
	3	Not Inspected	
	4	Not Inspected	
	5	Not Inspected	
Gate 1	6	0.00	
	7	0.00	
	8	0.07	
	9	0.07	
	10	0.00	
	11	0.02	
	12	0.03	
	13	0.06	
	14	0.07	
	15	0.02	
	16	0.06	
Gate 2	17	0.04	
	18	0.06	
	19	0.02	
	20	0.00	
	21	0.08	
	22	0.03	
	23	0.03	
	24	0.00	
	25	0.00	
	26	0.02	Average Magnetic Particle Rating = 0.022
	27	0.04	
Gate 3	28	0.00	
	29	0.00	Ultrasonic Index = 3.3
	30	0.02	
	31	0.08	
	32	0.01	
	33	0.04	
	34	0.00	
	35	0.05	
	36	0.02	
	37	0.01	
	38	0.03	
Gate 4	39	0.01	
	40	0.00	
	41	0.05	
	42	0.04	
	43	0.00	
	44	0.02	
	45	0.04	
	46	0.01	
	47	0.05	
	48	0.00	
	49	0.01	
Gate 5	50	0.00	
	51	0.00	
	52	0.00	
	53	0.03	
	54	0.03	
	55	0.08	

Figure 16 - Magnetic Particle Rating of Open Hearth Vacuum Degassed Coupon 3A

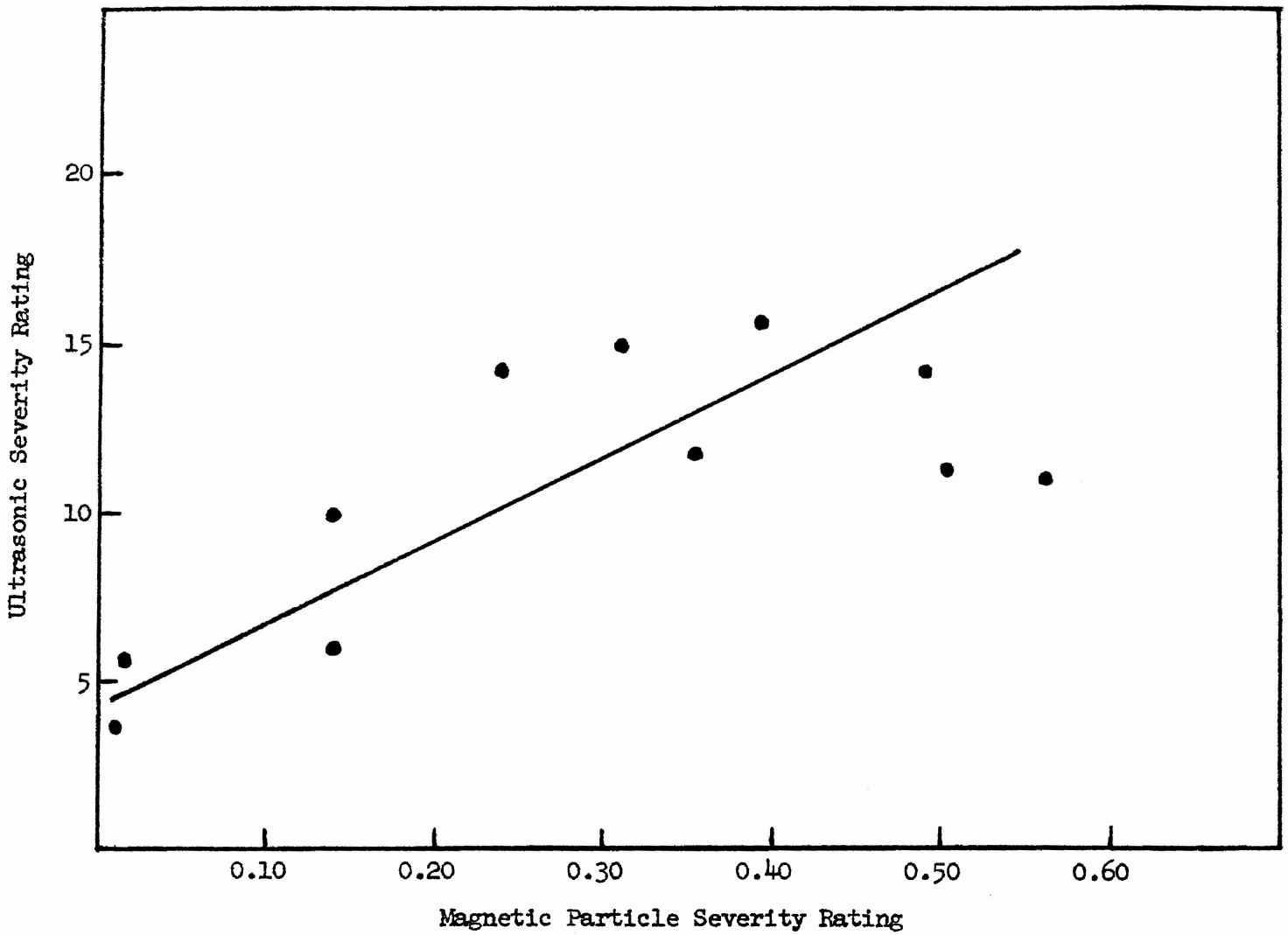


Figure 23 - Relation Between Ultrasonic Severity and Magnetic Particle Severity Rating

	SURFACE NUMBER	SEVERITY	
	1	Not Inspected	
	2	Not Inspected	
	3	Not Inspected	
	4	Not Inspected	
	5	Not Inspected	
Gate 1	6	0.00	
	7	0.00	
	8	0.00	
	9	0.00	
	10	0.02	
	11	0.00	
	12	0.00	
	13	0.00	
	14	0.00	
	15	0.00	
	16	0.00	
Gate 2	17	0.00	
	18	0.00	
	19	0.00	
	20	0.00	
	21	0.00	
	22	0.00	
	23	0.00	
	24	0.00	
	25	0.00	
	26	0.00	Average Magnetic Particle
	27	0.00	Rating = 0.0055
Gate 3	28	0.00	
	29	0.00	Ultrasonic Index = 231.4
	30	0.01	
	31	0.05	
	32	0.00	
	33	0.00	
	34	0.00	
	35	0.00	
	36	0.00	
	37	0.00	
	38	0.00	
Gate 4	39	0.00	
	40	0.00	
	41	0.00	
	42	0.00	
	43	0.00	
	44	0.00	
	45	0.00	
	46	0.00	
	47	0.00	
	48	0.00	
	49	0.00	
Gate 5	50	0.03	
	51	Not Inspected	
	52	Not Inspected	
	53	Not Inspected	
	54	Not Inspected	
	55	Not Inspected	

Figure 18 - Magnetic Particle Rating of Open Hearth Coupon 2G

OPEN HEARTH VACUUM DEGASSED 3A

CATEGORY	COUNT	FREQUENCY	P. FACTOR	PRODUCT
1	11,831	.0994	.5	.0497
2	61,915	.5203	1	.5203
3	25,610	.2152	2	.4304
4	10,955	.0920	4	.3682
5	4,900	.0412	8	.3294
6	2,060	.0173	16	.2770
7	960	.0081	32	.2581
8	407	.0034	64	.2189
9	183	.0015	128	.1967
10	107	.0009	256	.2301
11	54	.0005	512	.2319
12	18	.0002	1024	.1546
13	0	-	-	-
14	0	-	-	-
15	0	-	-	-
16	0	-	-	-

Calculated Index - 3.3

Figure 20 - Ultrasonic rating determined from cumulative counts that occurred for eighty-one scans (0.050" apart) in center gate.

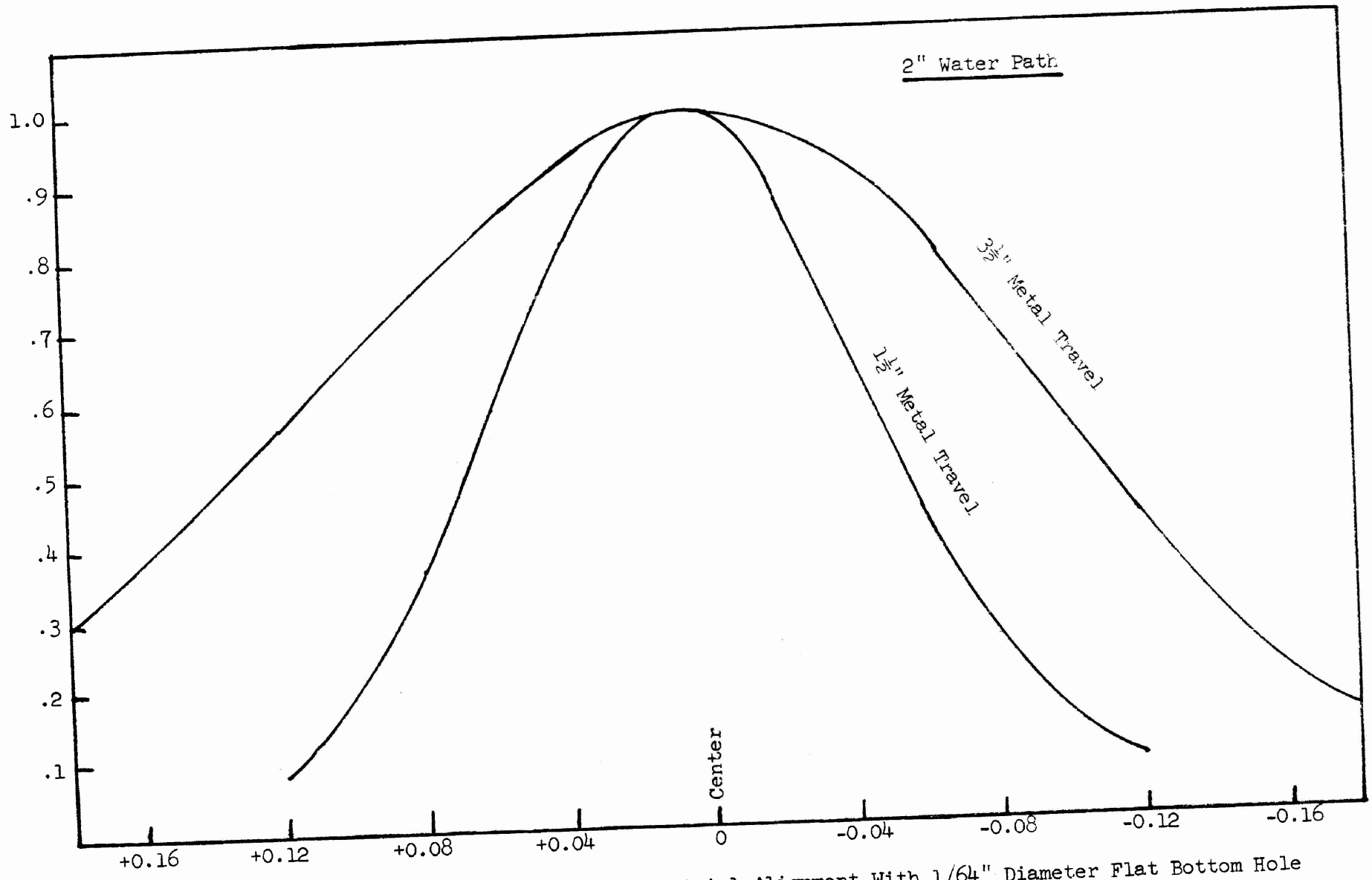


Figure 27(b) Effective Ultrasonic Coverage of 5 MC Lithium Sulfate Transducer (3/4" Dia.) with 7 inch Focal Length in Water

OPEN HEARTH 2G

CATEGORY	COUNT	FREQUENCY	P. FACTOR	PRODUCT
1	22,000	.1598	.5	.0799
2	52,090	.3784	1	.3783
3	28,151	.2045	2	.4089
4	14,149	.1028	4	.4110
5	7,116	.0517	8	.4135
6	3,718	.0270	16	.4320
7	2,327	.0169	32	.5408
8	1,528	.0111	64	.7103
9	1,293	.0094	128	1.2021
10	997	.0072	256	1.8539
11	897	.0065	512	3.3358
12	672	.0049	1024	4.9982
13	490	.0036	2048	7.2890
14	388	.0028	4096	11.5433
15	387	.0028	8192	23.0277
16	1,469	.0106	16384	174.8205

Calculated Index - 231.4

Figure 22 - Ultrasonic rating determined from cumulative counts that occurred for eighty-one scans (0.050" apart) in center gate.

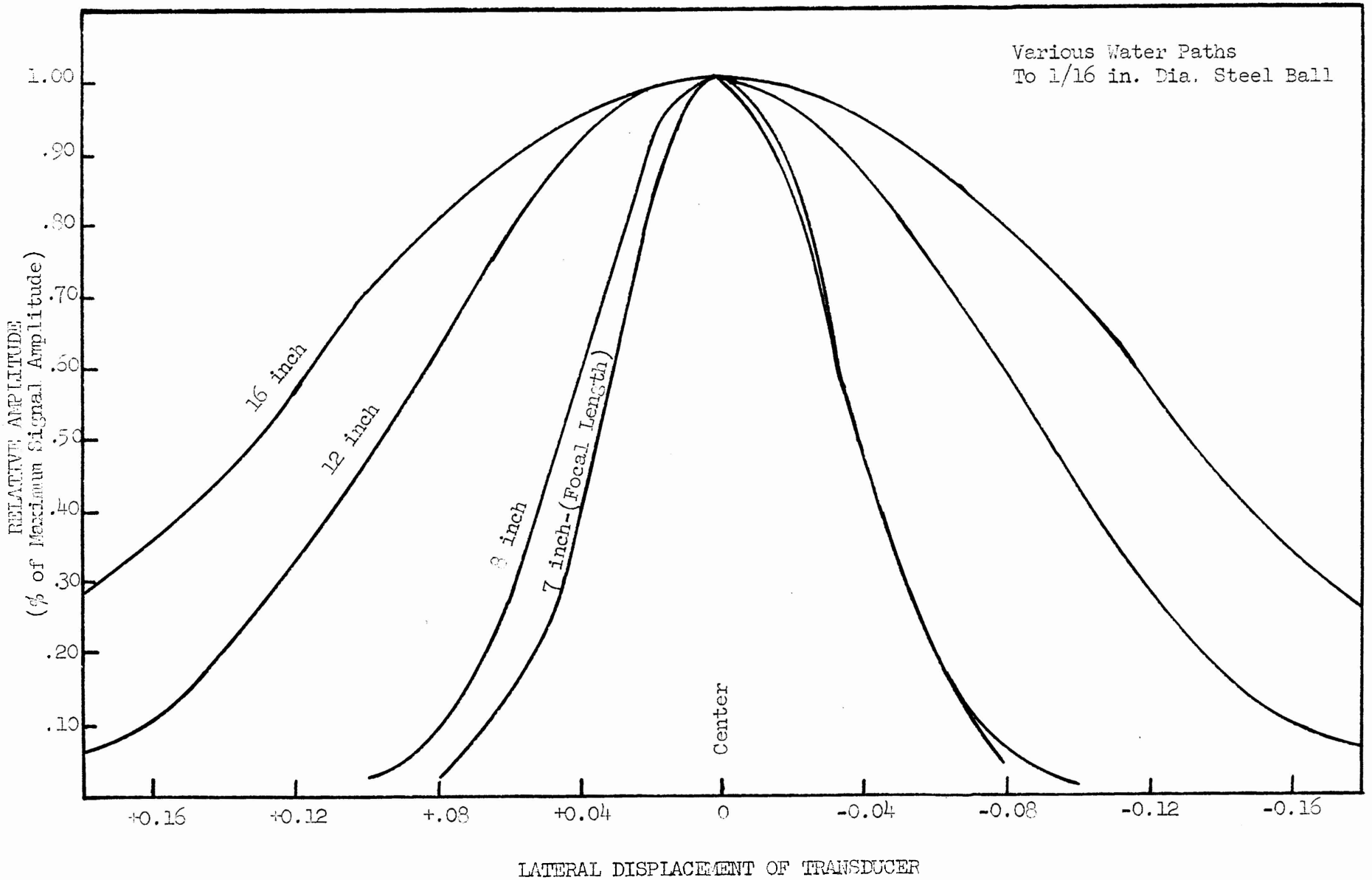


Figure 27 (d) Effective Ultrasonic Coverage of 5MC Lithium Sulfate Transducer (3/4" Dia.)

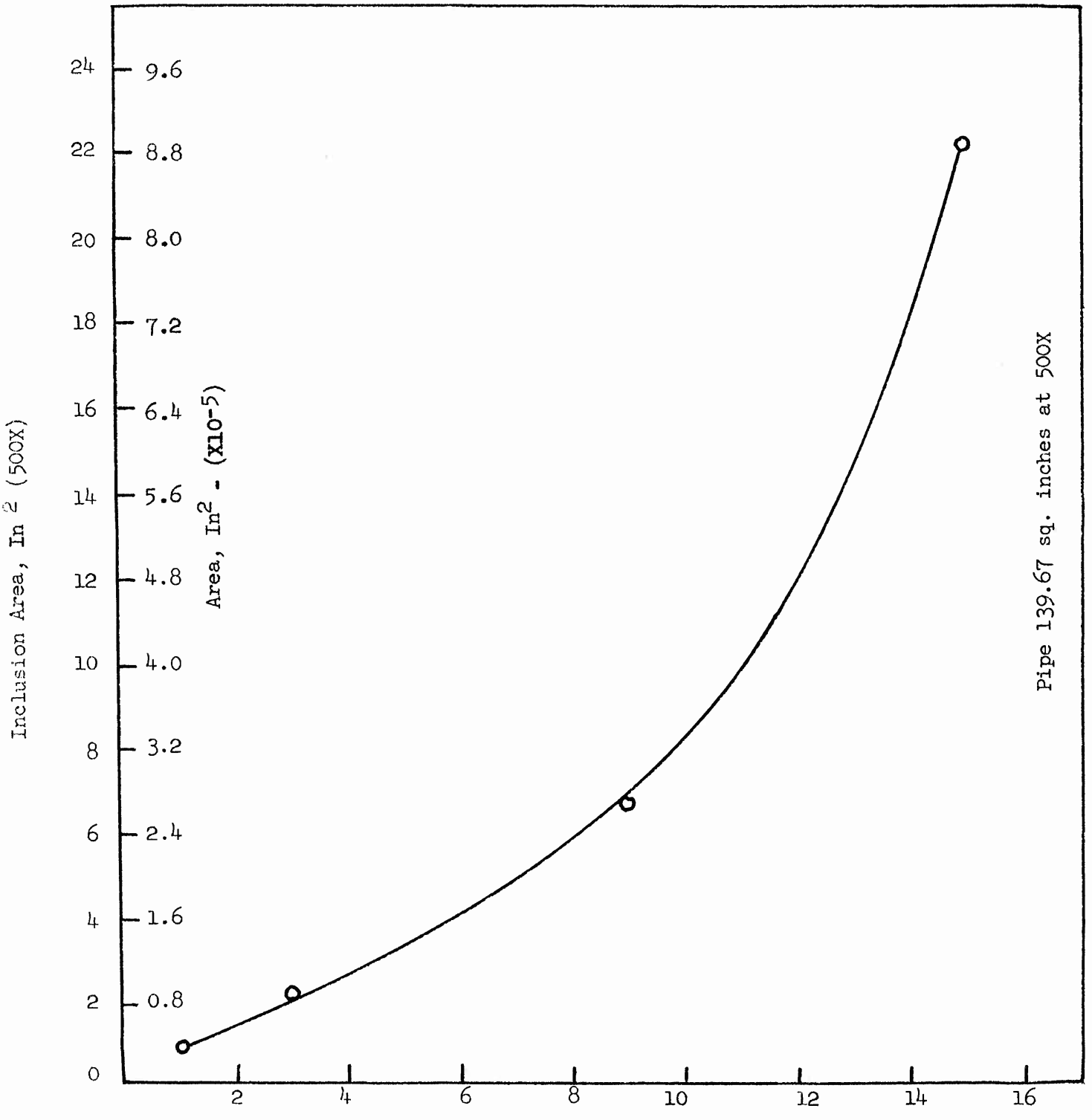


FIGURE: 24 - ACTUAL INCLUSION AREA AS MEASURED BY LIGHT MICROSCOPE VERSUS ULTRASONIC INCLUSION CATEGORY

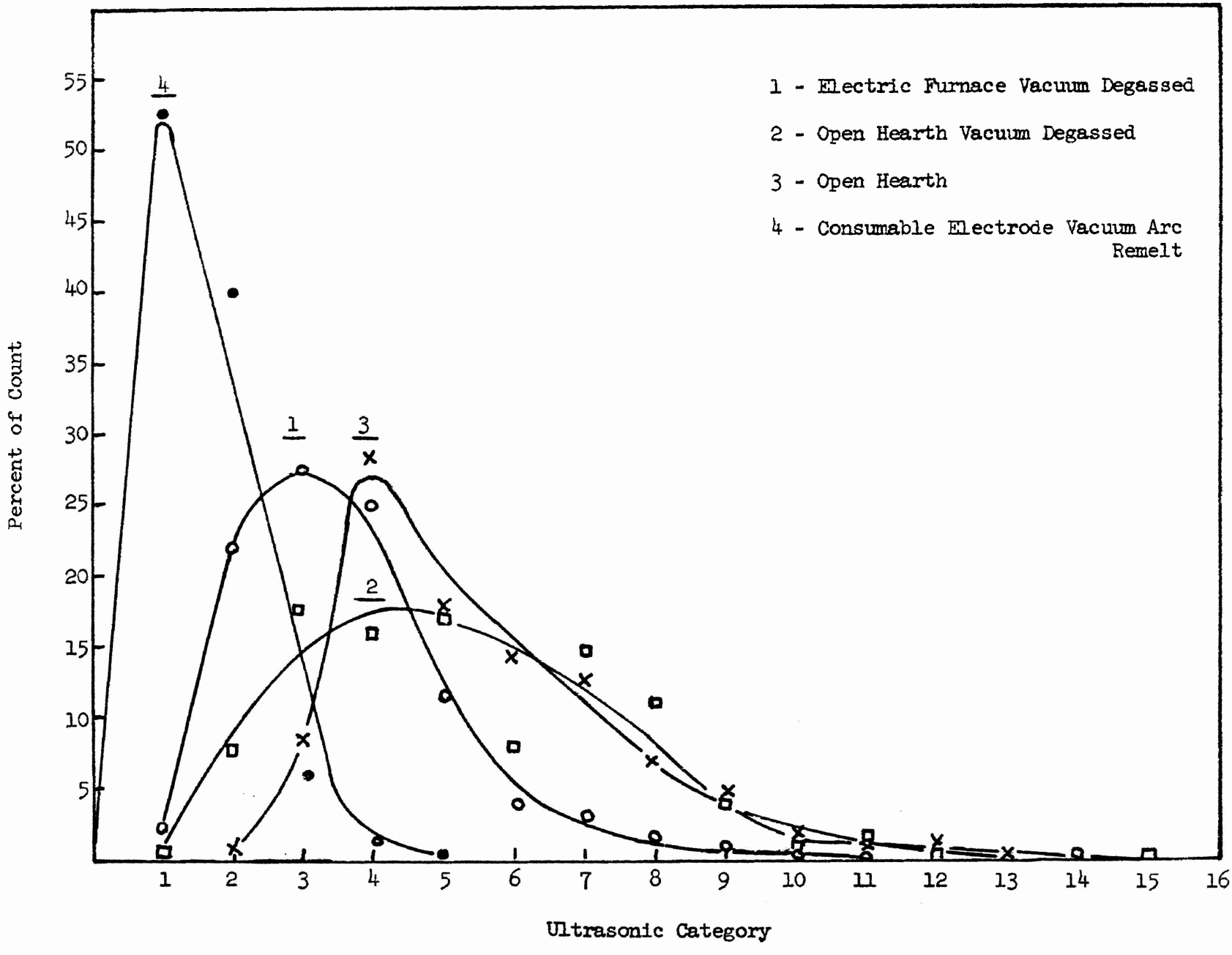
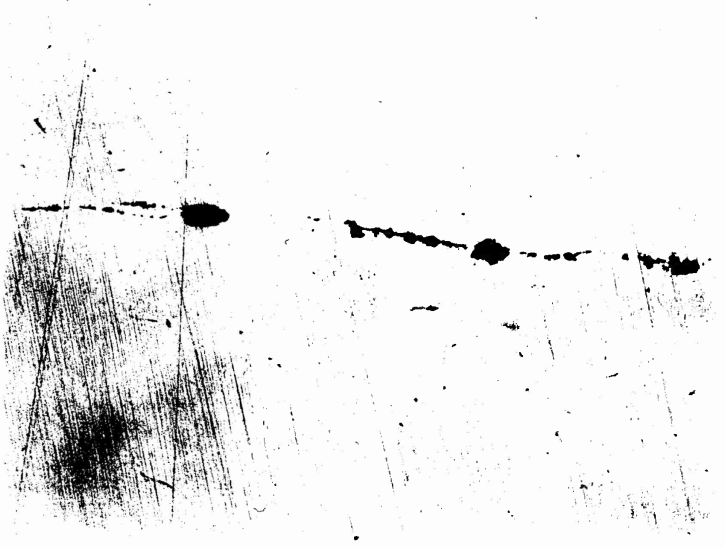
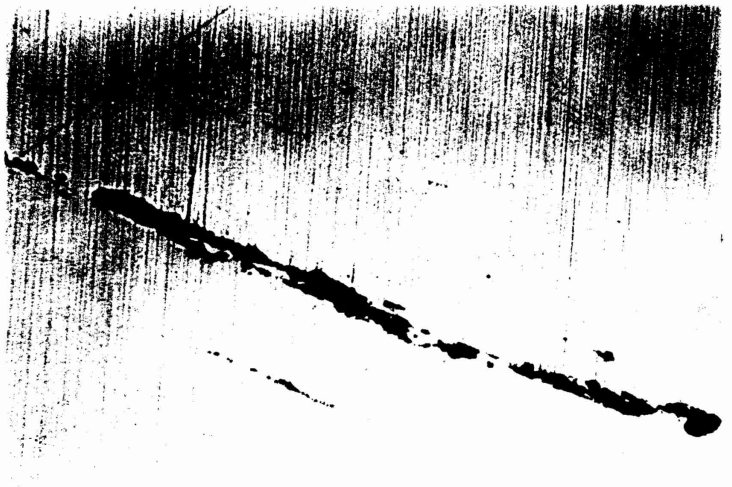


Figure 28 - Ultrasonic Inclusion Severity Rating of AISI 4340 Steel Standards

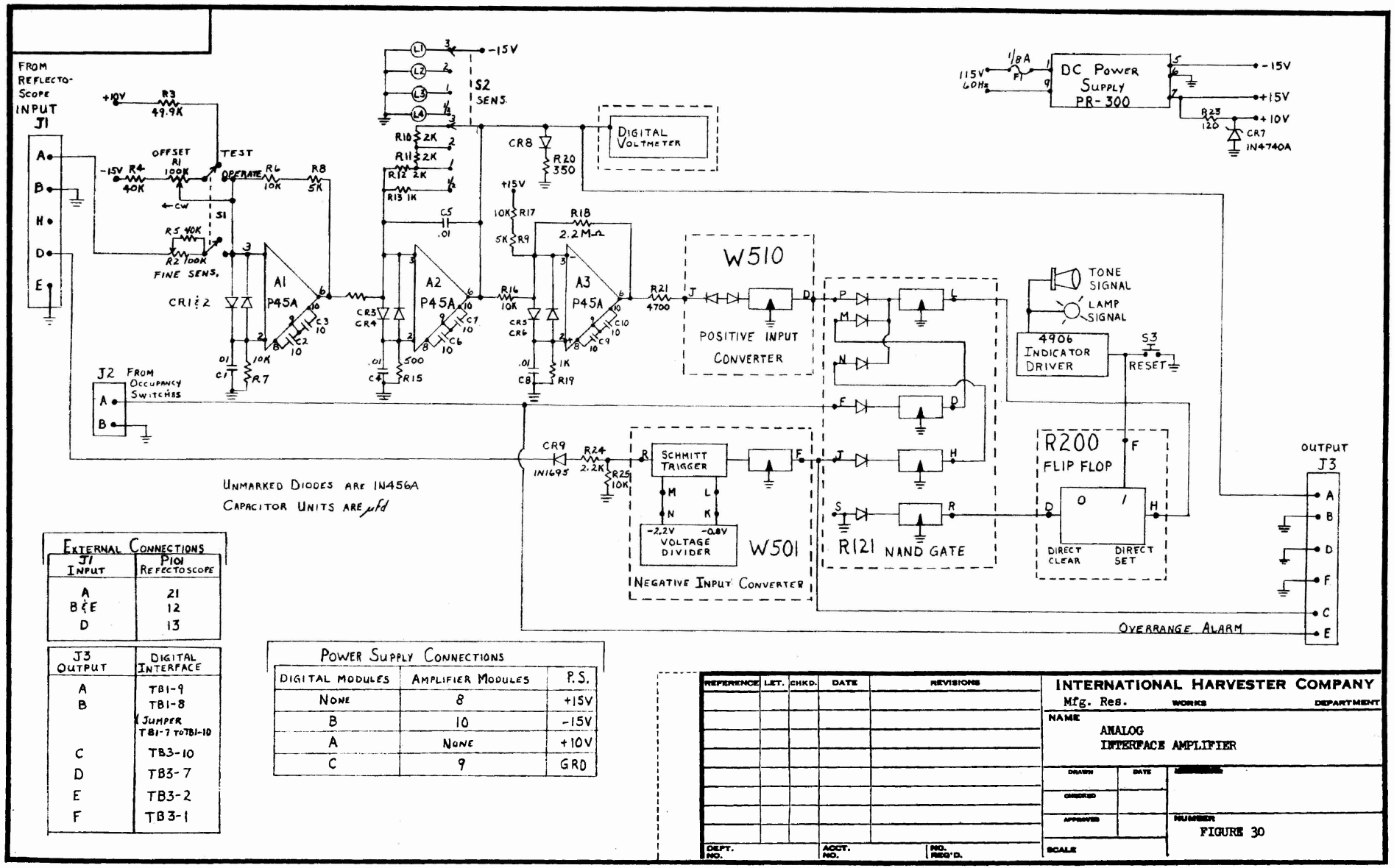


CATEGORY 3



CATEGORY 9

FIGURE 25 - PHOTOMICROGRAPH OF NONMETALLIC INCLUSIONS (100X) REPRESENTATIVE OF ULTRASONIC INCLUSION CATEGORIES 3 AND 9.



External Connections

J1 Input	P101 Refectoscope
A	21
B & E	12
D	13

J3 Output	Digital Interface
A	TB1-9
B	TB1-8 (Jumper TB1-7 to TB1-10)
C	TB3-10
D	TB3-7
E	TB3-2
F	TB3-1

Power Supply Connections

Digital Modules	Amplifier Modules	P.S.
None	8	+15V
B	10	-15V
A	None	+10V
C	9	GRD

Reference	Let.	Chkd.	Date	Revisions

Dept. No. | Acct. No. | No. Req'd.

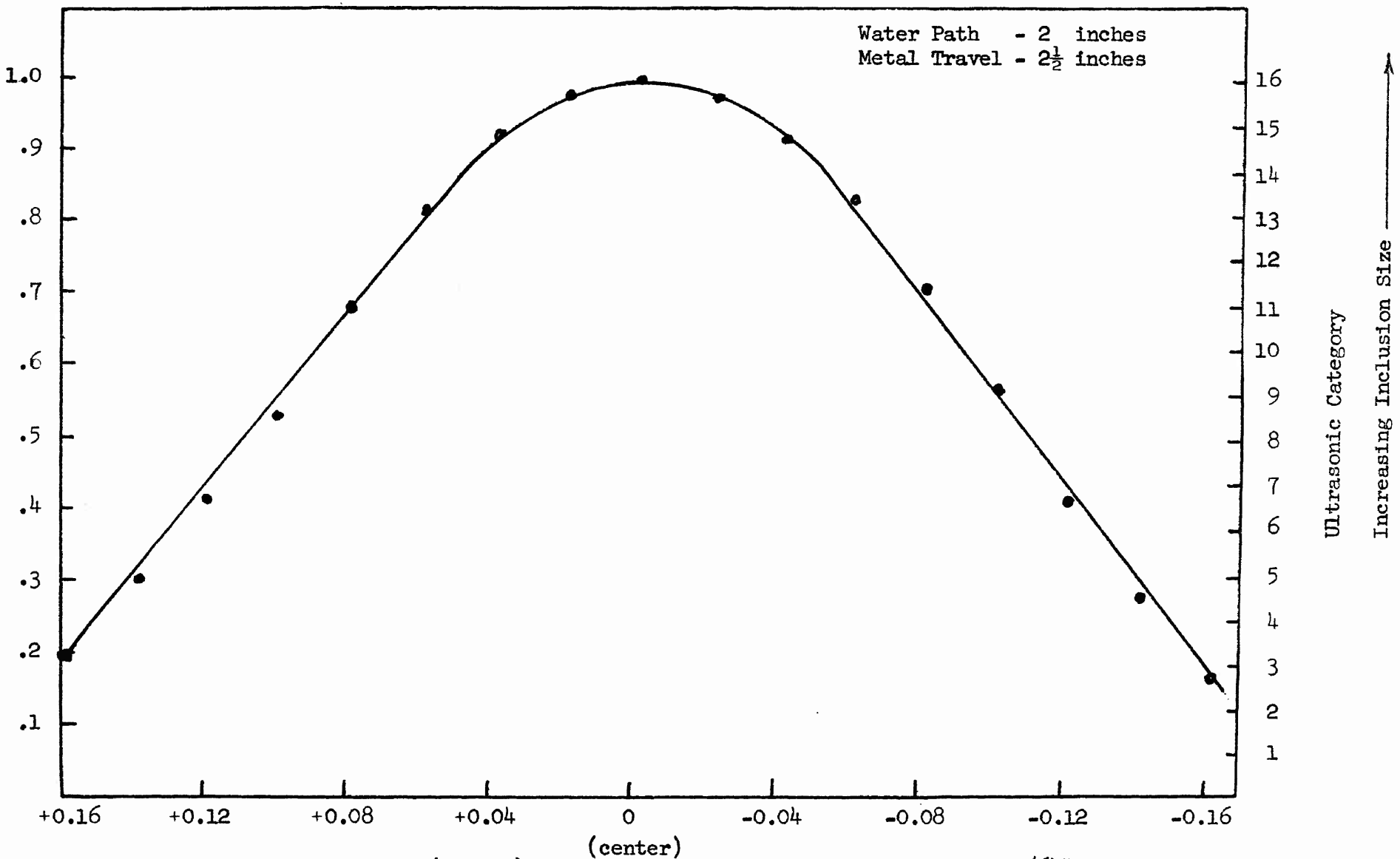
International Harvester Company

Mfg. Res. | Works | Department

Name: Analog Interface Amplifier

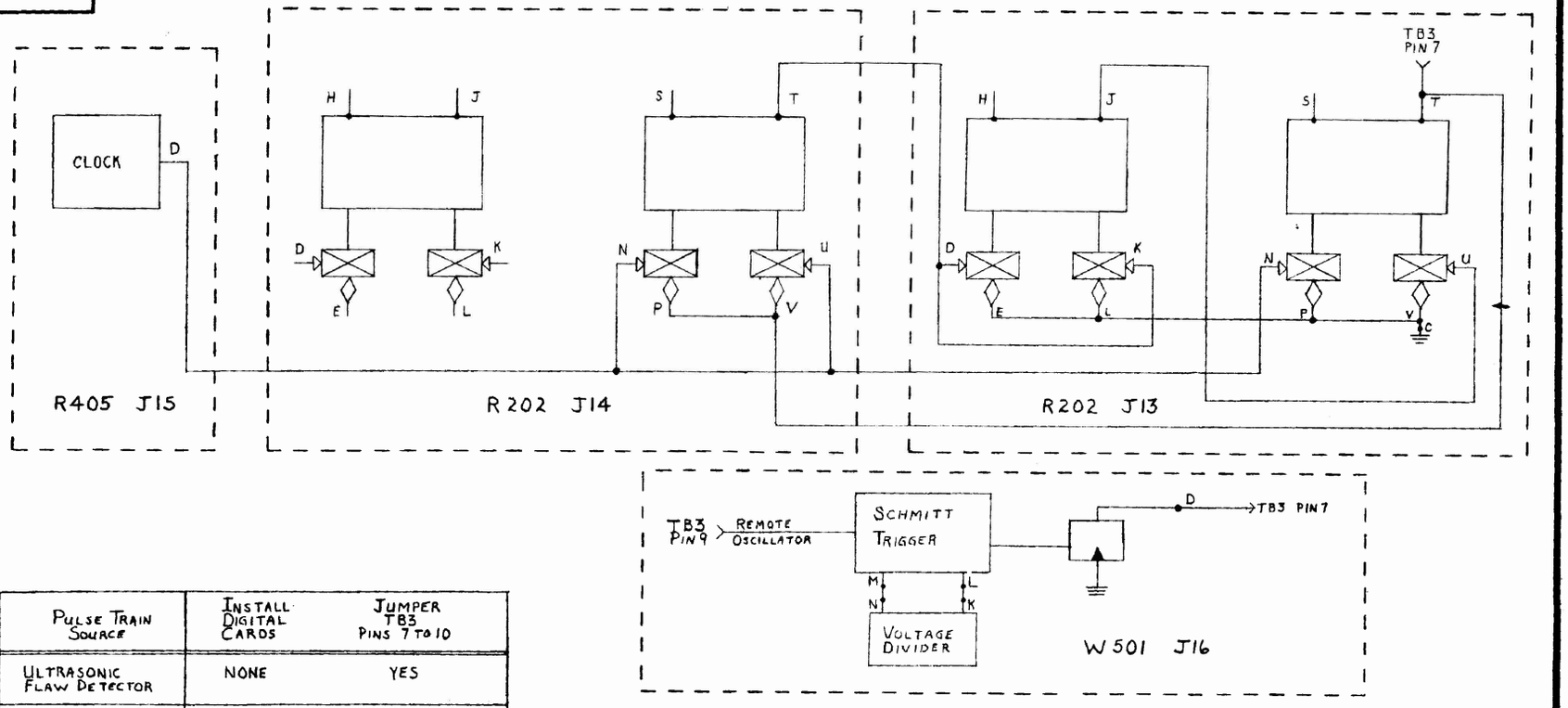
Drawn | Date | Checked | Approved | Scale

Number: FIGURE 30



Lateral Displacement (inches) of Transducer from Axial Alignment with 1/64" Dia. Flat Bottom Hole.

Figure 27a Effective Ultrasonic Inspection Coverage of 5 MC Lithium Sulfate Transducer (3/4" Dia.) with 7 inch Focal Length in Water.



PULSE TRAIN SOURCE	INSTALL DIGITAL CARDS	JUMPER TB3 PINS 7 TO 10
ULTRASONIC FLAW DETECTOR	NONE	YES
INTERNAL PULSE GENERATOR	R202 IN J13 R203 IN J14 R403 IN J15	NO
EXTERNAL OSCILLATOR	W501 IN J16	NO

REFERENCE	LET.	CHKD.	DATE	REVISIONS

DEPT. NO. | ACCT. NO. | NO. REQ'D.

INTERNATIONAL HARVESTER COMPANY

Mfg. Res. WORKS DEPARTMENT

NAME DIGITAL INTERFACE
PULSE TRAIN
MAINTENANCE TEST FACILITY

DRAWN | DATE | MATERIAL

CHECKED

APPROVED | NUMBER

SCALE

FIGURE 32

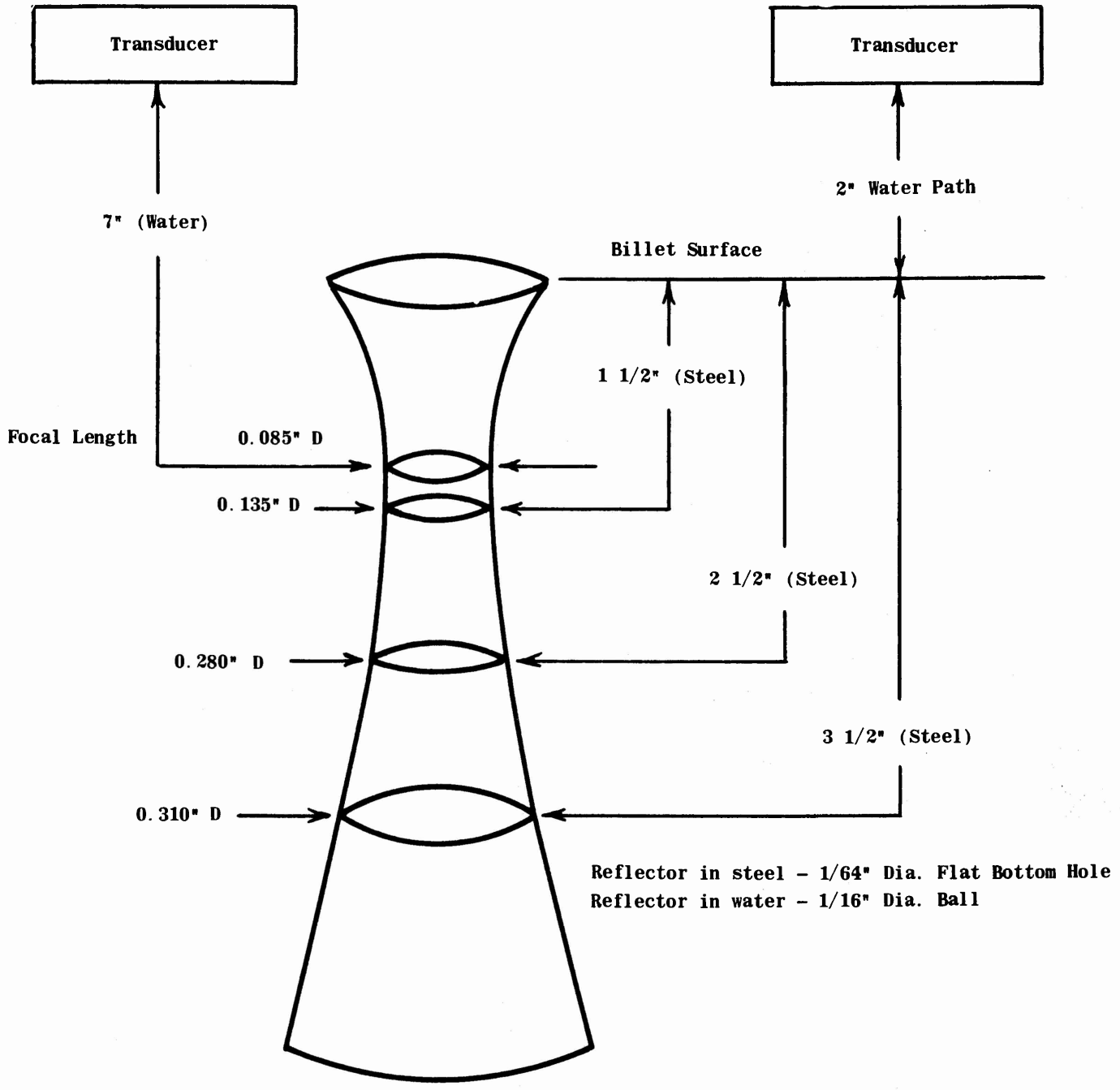


Figure 27 (C) Areas of Ultrasonic Inspection coverage at various Levels in steel for a 5MC Lithium Sulfate Transducer with 7 inch Focal Length. (30 to 100% maximum Signal Amplitude)

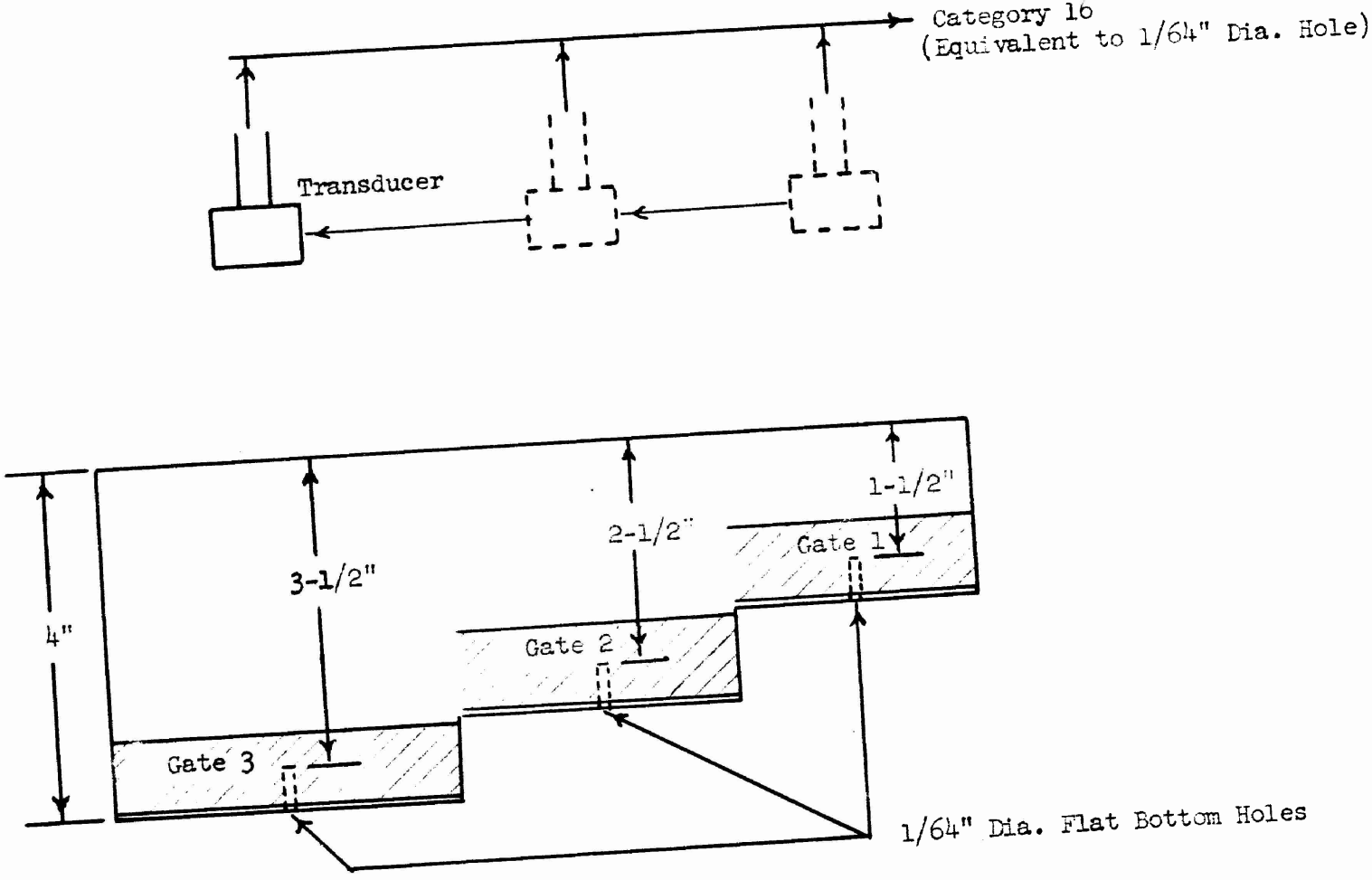


Figure 37 - Calibration Method of Adjusting Gain Setting to Correct for Ultrasonic Attenuation Losses Due to Material Depth

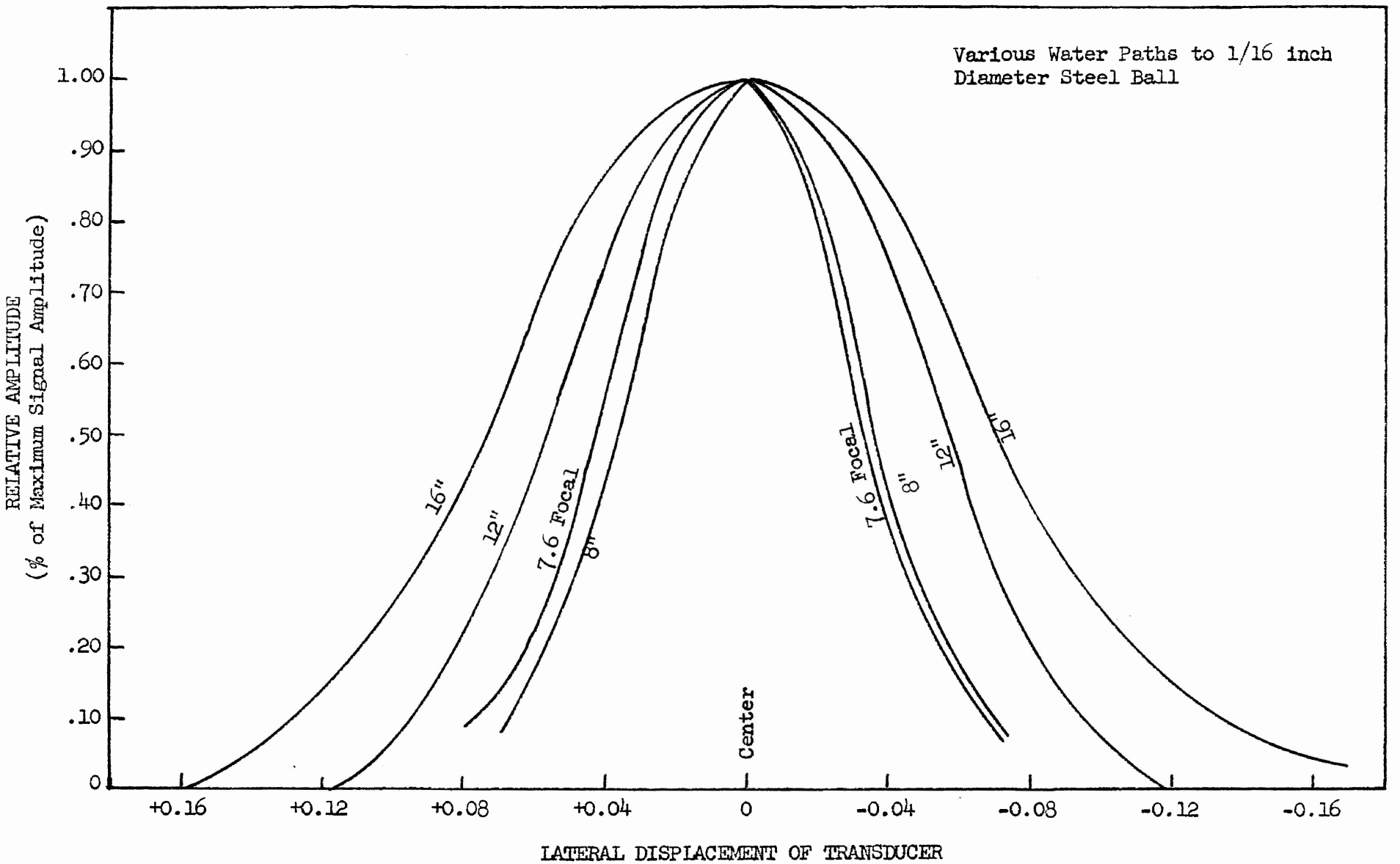


Figure 27(e) Effective Ultrasonic Coverage of 10MC Lithium Sulfate Transducer (3/4" Dia.)

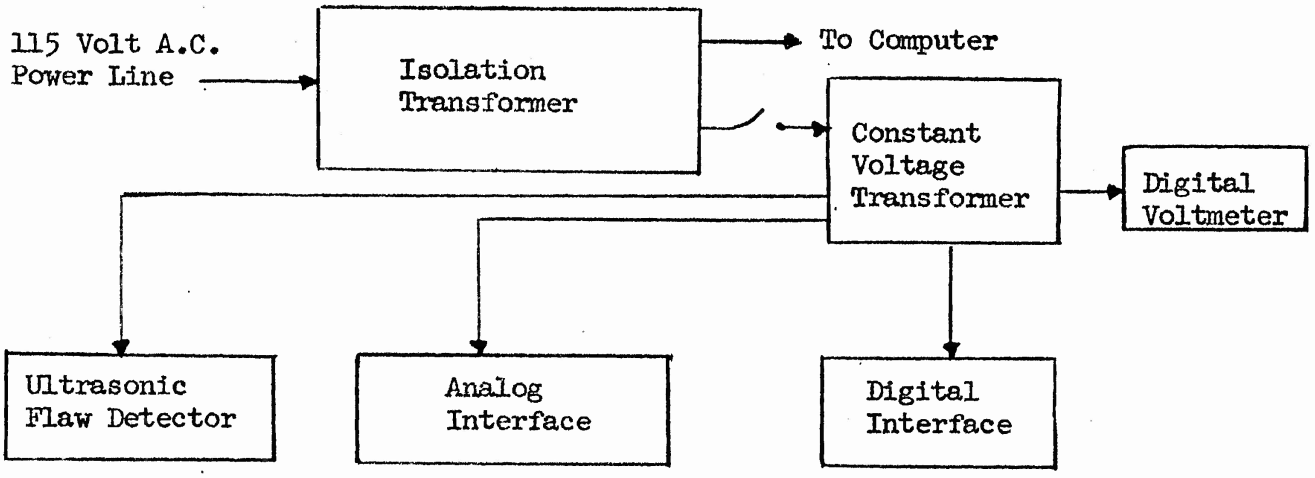
TABLE II

COMPARISON OF ULTRASONIC AND
AMS 2301 CLEANLINESS RATINGS

	Surface No.	AMS Severity	Average AMS Rating	Average Ultrasonic Rating
GATE 1	H	0.00	0.28	2.17
	.8H	0.03		
	.6H	0.54		
	.4H	0.55		
GATE 2	.2H	0.42	0.36	21.52
	.2H	0.29		
GATE 3	.4H	0.11	0.07	2.71
	.6H	0.04		
	.8H	0.10		
	H	0.02		

Ultrasonic Station Internal Cabling

Power Cabling



Signal Cabling

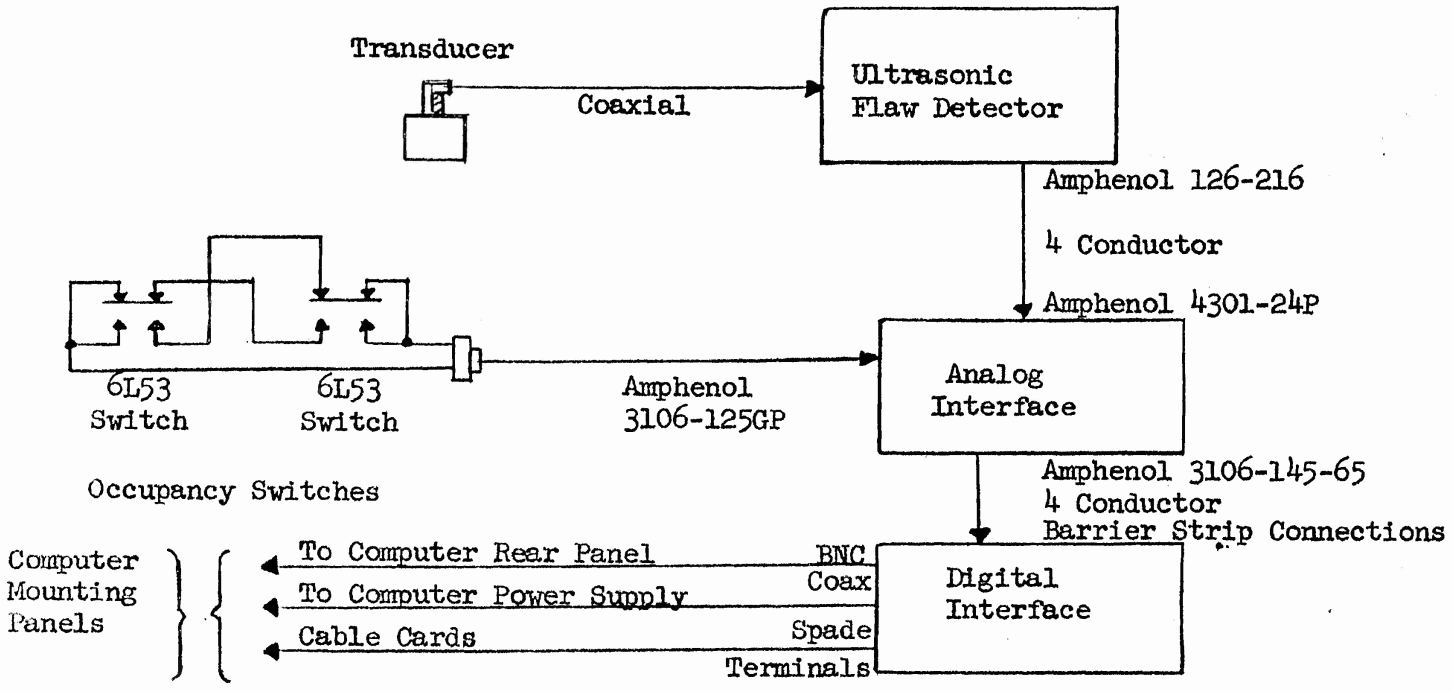


Figure 29 - Internal Cabling Diagram

TABLE IV

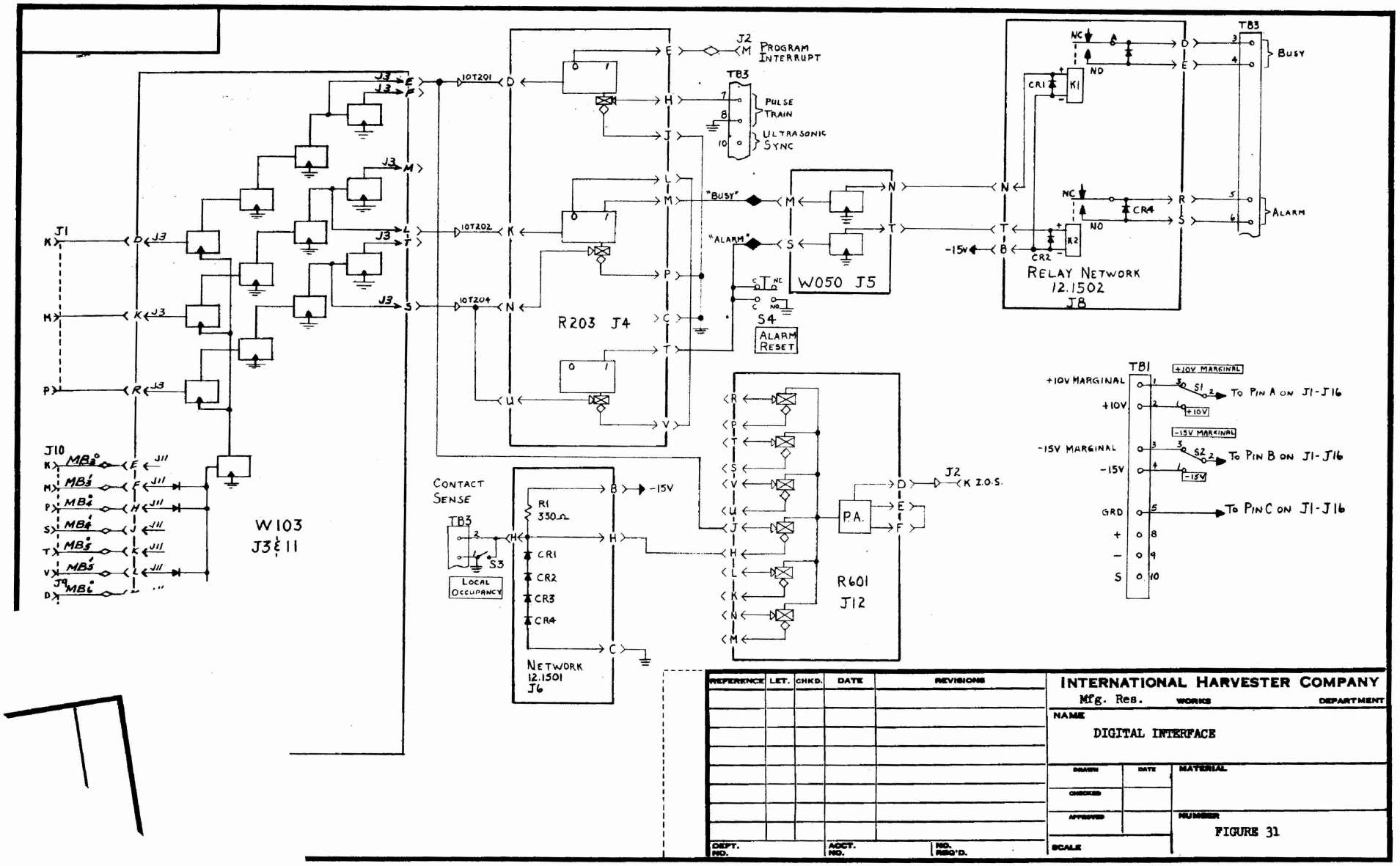
ULTRASONIC CLEANLINESS RATING

OF OPEN HEARTH

COUPON 3H

LATERAL POSITION OF SCAN (INCHES)

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Avg.of all 21 scans	Avg.of Ctr 3 scans (-0.2" to +0.2")
Gate 1		0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.8	0.9	0.8	0.8	0.8	0.7	0.8	0.8	0.8
Gate 2	0.6	0.5	0.6	0.7	0.8	0.9	0.9	0.9	1.0	1.1	1.4	1.2	1.1	0.9	1.0	0.9	0.9	0.9	0.8	0.7	0.6	0.9	1.2
Gate 3	0.8	1.0	1.6	1.7	2.3	3.1	4.0	3.2	4.6	7.8	11.7	6.7	7.1	6.2	5.3	6.2	6.4	3.7	3.0	2.9		4.5	8.7
Gate 4	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.3	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	0.8	0.8	0.7	0.5	0.9	1.1
Gate 5		0.7	0.7	0.9	0.9	1.0	1.1	1.1	1.0	0.9	0.9	0.9	1.0	0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.8	0.9



REFERENCE	LET.	CHKD.	DATE	REVISIONS

INTERNATIONAL HARVESTER COMPANY
Mfg. Res. WORKS DEPARTMENT

NAME
DIGITAL INTERFACE

DRAWN | DATE | MATERIAL
CHECKED
APPROVED | NUMBER
SCALE

FIGURE 31

DEPT. NO. | ACCT. NO. | NO. REQ'D.

TABLE VI

MAGNETIC PARTICLE SEVERITY

RATING OF

OPEN HEARTH COUPON 3H

LATERAL POSITION OF BILLET INSPECTION (INCHES)

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Average of center 3 scans (-0.2" to +0.2")
Gate 1				0.19		0.19			0.19							0.19						0.00
Gate 2												0.19	0.53									0.06
Gate 3									1.15	3.85	14.40	2.30	0.77									6.85
Gate 4					0.19						2.12									0.38		0.71
Gate 5																						0.00

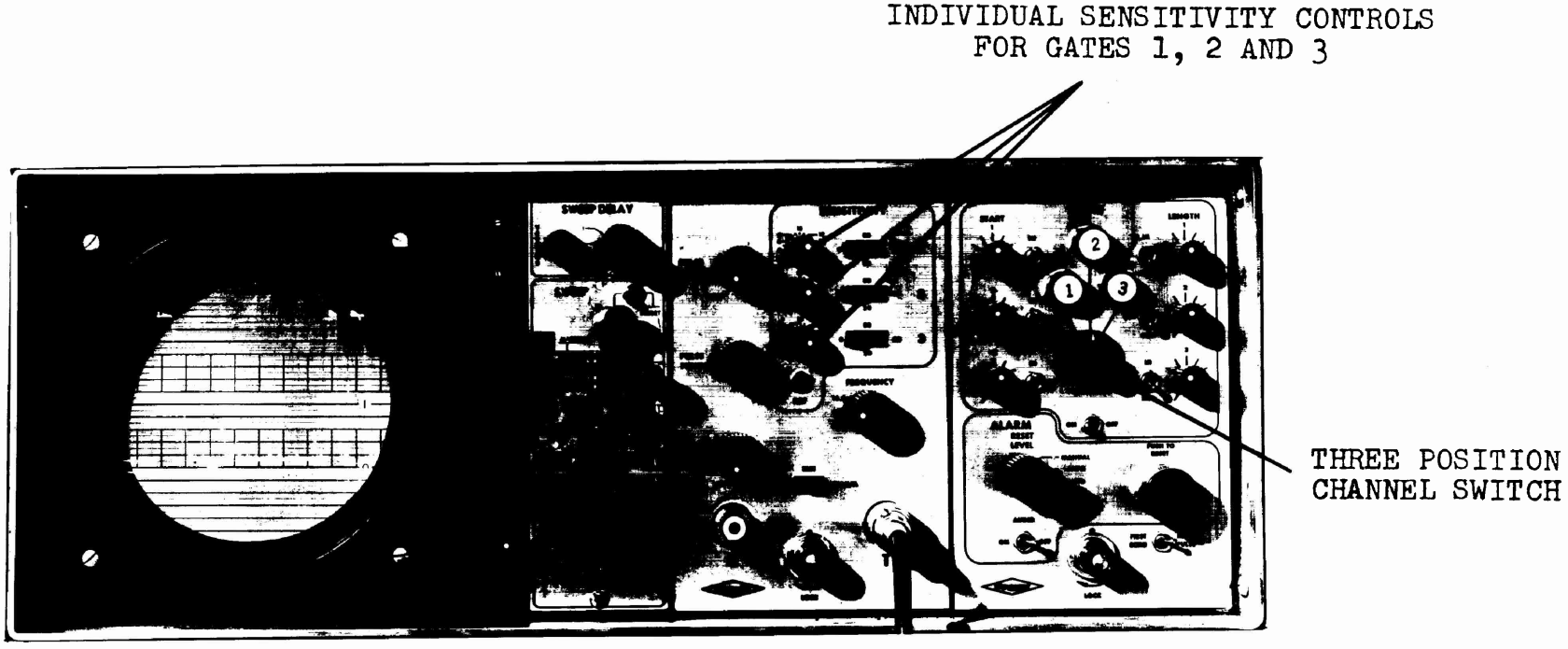


FIGURE 33 - ULTRASONIC MAINFRAME

TABLE VIII

MAGNETIC PARTICLE SEVERITY RATING

OF

CONSUMABLE ELECTRODE VACUUM ARC REMELT COUPON 2I

LATERAL POSITION OF BILLET INSPECTION (INCHES)

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0
Gate 1																					
Gate 2											ALL INCLUSIONS 0.030" AND UNDER										
Gate 3											ALL INCLUSIONS 0.030" AND UNDER										
Gate 4																					
Gate 5																					

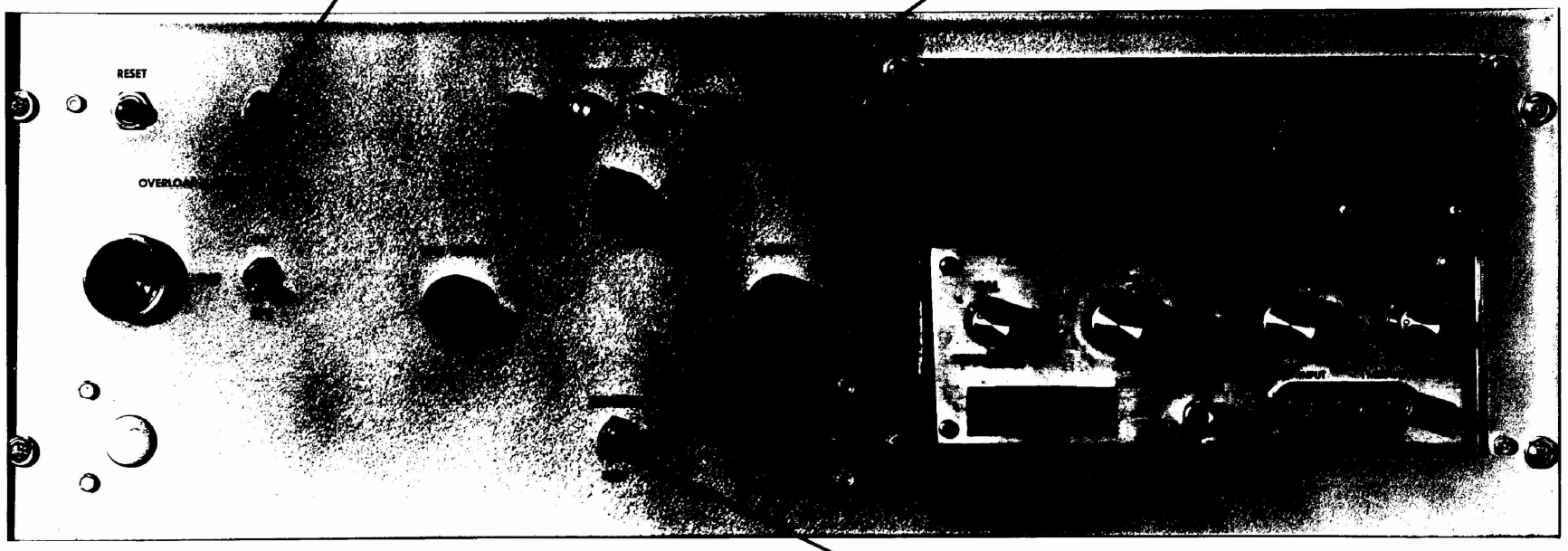


FIGURE 34 - ANALOG INTERFACE MODULE

TABLE X

ULTRASONIC CLEANLINESS RATING

ELECTRIC FURNACE VACUUM DEGASSED COUPON 2C

LATERAL POSITION OF SCAN (INCHES)

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Average of center scans (-0.2" to +0.2")
Gate 1			0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.6		0.5
Gate 2			0.6	0.6	0.6	0.6	0.8	0.7	0.8	0.8	0.7	0.7	0.8	0.7	0.8	0.7	0.6	0.6	0.6			0.7
Gate 3		1.8	1.3	1.5	1.6	2.2	2.7	3.5	3.3	4.6	6.6	5.6	3.2	2.5	2.7	2.0	1.8	1.4	1.5	1.1	1.1	6.8
		1.6	1.2	1.3	1.9	2.4	2.6	4.2	4.8	4.6	12.6	5.6	2.7	2.5	2.2	1.7	1.9	1.5	1.5	1.1		
		1.2	1.3	1.3	1.9	2.6	2.6	3.2	5.2	5.0	12.8	5.4	3.4	3.3	2.0	1.6	1.8	1.6	1.4	1.3		
			1.5	1.4	2.1	2.5	3.0	2.7	4.7	5.6	7.2	5.5	2.9	3.2	2.0	1.6	1.5	1.5	1.1	1.3		
Gate 4	0.8	0.8	0.6	0.6	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.6	0.6			0.9
Gate 5		0.6	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.6			0.8

OPEN HEARTH COUPON 3G

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Average of center scans (-0.2" to +0.2")
Gate 1	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.5	0.8	0.6
Gate 2		0.6	0.7	0.7	0.7	0.8	0.9	0.9	1.0	0.9	1.1	1.0	1.0	0.9	1.0	0.9	1.0	1.0	1.0	1.0	0.9	1.0
Gate 3	0.5	0.7	1.0	1.3	1.3	1.3	1.7	1.5	2.3	3.8	8.6	3.8	4.0	2.1	1.8	1.6	1.7	1.9	1.1	1.1	0.5	5.8
	0.5	0.8	1.0	1.4	1.2	1.4	1.7	1.4	28.0	3.4	5.2	3.8	2.7	1.7	2.2	1.8	1.5	1.8	1.0	0.8		
	0.6	0.8	1.0	1.4	1.2	1.4	1.7	1.7	99.1	6.7	5.3	3.7	1.9	1.6	1.9	1.8	1.9	1.5	1.1	0.7		
	0.7	0.9	1.2	1.3	1.2	1.5	1.7	1.9	23.9	17.2	4.4	3.6	1.9	1.6	1.7	1.8	2.0	1.5	1.3	0.6		
Gate 4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5		0.6
Gate 5	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.7	0.5	0.5

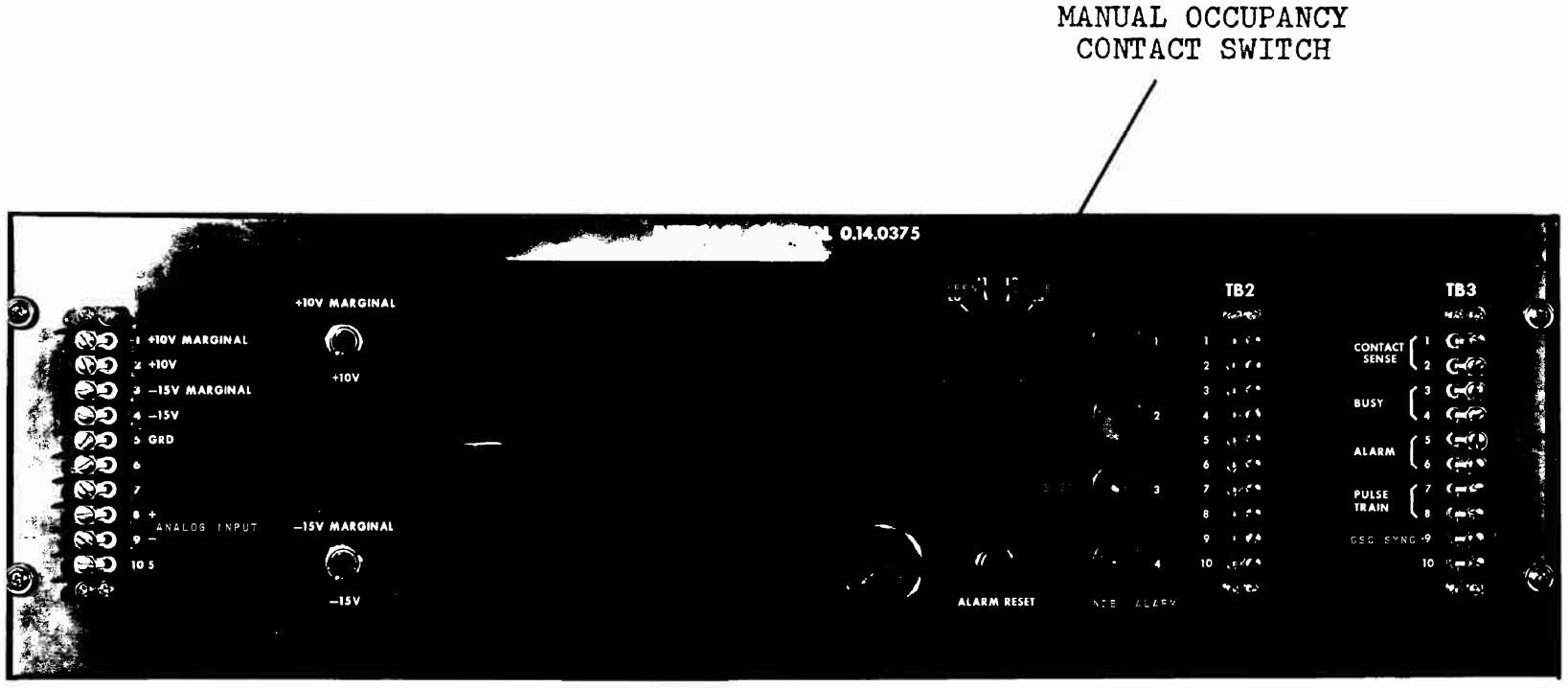


FIGURE 35 - DIGITAL INTERFACE MODULE

TABLE XII

MAGNETIC PARTICLE SEVERITY RATING

LATERAL POSITION OF BILLET INSPECTION (INCHES)

ELECTRIC FURNACE VACUUM DEGASSED COUPON 2C

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Average of center scans (-0.2" to +0.2")
Gate 1														.38								0.00
Gate 2																						0.00
Gate 3	.19									.19		.38			.19							0.19
Gate 4				.19														.19	.38			0.19
Gate 5	.38	.96			.58	.19	.19	.77	.19	.77		.19				.19	.19		.19	.19	.19	0.32

OPEN HEARTH COUPON 3G

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Average of center scans (-0.2" to +0.2")
Gate 1																						0.00
Gate 2																						0.00
Gate 3					.58	.77		.19		8.46	4.62	10.38					.19			.19	.19	7.82
Gate 4		.38																				0.00
Gate 5		.19																				0.00

Analog Interface Module

Symbol	Part Number	Description
C1,C4,C5,C8,C11	Sprague 5HK-S10	.01 µf-1000V Capacitor
C2,C3,C6,C7,C9,C10	Sprague TE 1204	10 µf-25V Capacitor
CR1,2,3,4,5,6,8	IN456A	Diode
CR7	IN4740A	Diode
CR9	IN1695	Diode
R1, R2	Clarostat 62-JA	100K, 10 Turn Pot
R3	IRC HEA-T2	49.9K Resistor
R4, R5	IRC WW10J	40K Resistor
R6, R7, R16, R17	"	10K "
R8, R9, R14, R15	"	500 OHM Resistor
R10, R11, R12	"	2K "
R13	"	1K "
R18	1/2 Watt 5%	2.2 Megohms Resistor
R19	"	1K "
R20	"	350 "
R21	"	4700 "
R22	"	2700 "
R23	"	120 "
A1, A2, A3	Philbrick P45A	Differential Amplifiers
PR-300	Philbrick	Power Supply
W510	Dec	Positive Input Converter
R121	Dec	Hand Gate
R200	Dec	Flip Flop
W501	Dec	Negative Input Converter
H800F	Dec	Connector Block
Tone Signal	Mallory SC 628	"Sonalert"
Counting Dials	Clarostat 411	
Digital Voltmeter	Hickock DMS-3200/DP100	
J1	Amphenol 126-010	Chassis Socket
J2	Amphenol 3102-14S-6S	" "
S1	Cutler Hammer ST-52N	Switch
S2	Shall Cross 1J 04 A6	Switch
S3	Grayhill 23-1	Switch
L1-L4	Dialco 257	Indicator Lights
Fuseholder	Littlefuse HKL	

Ultrasonic Cabinet Base

Fan	Rotron Sentinal	Filter Fan
Transformer	Jefferson Electric 222-091-120	Isolating Transformer
Transformer	Sola 23-22-150 CVS	Constant Voltage Transformer
L11	Dialco 95408H-931-NE51H	Lamp
S11	Cutler Hammer ST-52N	Switch

FIGURE 36 - Parts List for Analog Interface Module and Ultrasonic Rack

TABLE XIV

DETAILED MAGNETIC PARTICLE RATING
WITH INSPECTIONAL LEVELS 0.005 INCH APART

SURFACE NO.	AMS SEVERITY	SURFACE NO.	AMS SEVERITY
1	0.42	51	0.42
2	0.49	52	0.19
3	0.30	53	0.37
4	0.23	54	0.23
5	0.19	55	0.38
6	0.25	56	0.42
7	0.09	57	0.38
8	0.47	58	0.38
9	0.14	59	0.35
10	0.43	60	0.42
11	0.30	61	0.51
12	0.28	62	0.30
13	0.40	63	0.46
14	0.24	64	0.46
15	0.34	65	0.35
16	0.23	66	0.33
17	0.26	67	0.39
18	0.26	68	0.23
19	0.31	69	0.30
20	0.24	70	0.23
21	0.38	71	0.49
22	0.19	72	0.28
23	0.24	73	0.19
24	0.17	74	0.30
25	0.16	75	0.43
26	0.31	76	0.42
27	0.16	77	0.47
28	0.02	78	0.38
29	0.10	79	0.44
30	0.19	80	0.17
31	0.14	81	0.30
32	0.19	82	0.17
33	0.23	83	0.47
34	0.30	84	0.26
35	0.23	85	0.26
36	0.26	86	0.31
37	0.17	87	0.21
38	0.31	88	0.24
39	0.14	89	0.31
40	0.22	90	0.17
41	0.28	91	0.17
42	0.19	92	0.23
43	0.16	93	0.37
44	0.12	94	0.30
45	0.14	95	0.17
46	0.26	96	0.12
47	0.07	97	0.51
48	0.28	98	0.24
49	0.26	99	0.28
50	0.31	100	0.44
		101	0.33

TABLE I

ULTRASONIC CLEANLINESS RATINGS OF 4140 ELECTRIC FURNACE VACUUM DEGASSED STEEL

PASS NO.	TOP GATE	MIDDLE GATE	BOTTOM GATE (Billet Rotated 180° and Inspected at Top)
1	1.61	5.85	1.59
2	1.99	7.50	1.90
3	1.99	11.10	2.11
4	2.23	9.50	2.37
5	2.48	104.09	6.92
6	2.70	19.61	2.77
7	2.71	13.02	3.11
8	2.48	13.95	2.87
9	2.67	73.02	2.60
10	2.63	15.10	3.35
11	2.89	14.98	2.93
12	1.87	10.09	2.24
13	1.64	10.19	2.10
14	1.41	9.22	2.21
15	1.29	5.64	1.51
Average Rating	2.17	21.52	2.71

Note: All gates 0.8 inches in depth

TABLE XVI

ULTRASONIC CLEANLINESS RATINGS OF STANDARDS

STANDARD NO. 3

LATERAL POSITION OF SCAN (INCHES)

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0
Gate 1		0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.9	0.8	0.7	0.7	0.6
Gate 2	0.7	0.8	1.0	1.0	1.2	1.2	1.2	1.3	1.4	1.3	1.8	1.4	1.3	1.3	1.4	1.1	1.2	1.2	1.0	0.9	0.6
Gate 3	1.4	1.8	3.7	3.1	5.0	4.4	4.7	6.1	6.6	42.0	46.6	12.5	6.5	4.7	5.3	5.0	4.5	3.1	2.9	2.3	1.0
	1.5	2.2	3.2	3.6	4.4	4.3	5.8	6.0	7.3	28.5	28.6	15.0	6.1	5.6	6.1	4.5	4.5	3.7	2.4	1.7	
	1.5	3.1	3.0	4.3	3.5	4.0	6.5	5.9	9.4	22.2	21.1	12.2	5.1	5.7	7.0	4.6	3.9	4.1	2.5	1.4	
	1.6	4.2	3.1	5.1	3.9	4.3	7.0	6.8	30.7	31.4	9.8	7.6	4.3	5.5	6.4	4.3	3.4	3.3	2.4	1.2	
Gate 4	0.6	1.0	1.0	1.3	1.2	1.2	1.1	1.3	1.5	1.8	1.5	1.6	1.4	1.2	1.3	1.2	1.1	1.2	1.1	0.8	0.8
Gate 5	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.8	0.8	0.8	0.8	1.0	0.8	0.7	0.7	0.6	0.6	0.6	

STANDARD NO. 4

Gate 1		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Gate 2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Gate 3	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.5	
	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5	
	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.7	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	
	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.9	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5	
											0.9										
Gate 4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Gate 5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

TABLE III
ULTRASONIC CLEANLINESS RATING

OF
CONSUMABLE ELECTRODE VACUUM ARC REMELT
COUPON 2I

LATERAL POSITION OF SCAN (INCHES)

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Avg.of all 21 Scans	Avg.of Ctr 3 Scans (-0.2" to +0.2")
Gate 1		0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.6	0.6	0.7	0.7	0.6	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.7
Gate 2	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.7	0.8
Gate 3	0.6	1.0	1.3	1.6	1.7	1.9	2.1	2.7	2.3	2.2	2.6	2.8	3.1	2.1	2.7	1.8	1.6	1.4	1.3	1.0	0.7	1.8	2.5
Gate 4	0.6	0.5	0.6	0.6	0.7	0.8	0.8	0.8	0.9	0.8	0.8	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.5		0.7	0.8
Gate 5		0.6	0.7	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8		0.7	0.7

TABLE V

ULTRASONIC CLEANLINESS RATING

OF

ELECTRIC FURNACE VACUUM DEGASSED

COUPON 1F

LATERAL POSITION OF SCAN (INCHES)

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Avg. of all 21 scans	Avg.of Ctr 3 scans (-0.2" to +0.2")
Gate 1		0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7
Gate 2	0.5	0.5	0.6	0.6	0.6	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.7	0.7	0.7	0.6	0.6	0.5	0.7	0.9
Gate 3	0.6	1.0	1.5	1.7	2.0	2.7	3.6	4.5	5.8	6.7	20.8	18.9	8.6	6.0	4.0	5.0	3.2	2.0	2.6	1.8	1.3	5.0	15.5
Gate 4	0.5	0.5	0.5	0.6	0.6	0.8	0.9	0.8	0.8	0.8	1.0	0.9	1.0	0.9	0.8	0.8	0.8	0.7	0.8	0.6	0.5	0.7	0.9
Gate 5	0.9	0.6	0.6	0.5	0.6	0.6	0.7	0.6	0.6	0.7	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.8	0.7		0.7	0.7

TABLE VII

MAGNETIC PARTICLE SEVERITY RATING

OF

ELECTRIC FURNACE VACUUM DEGASSED COUPON 1F

LATERAL POSITION OF BILLET INSPECTION (INCHES)

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Average of center 3 scans (-0.2" to +0.2")
Gate 1																						0.00
Gate 2									0.19	0.19	0.38		0.38	0.19	0.19							0.19
Gate 3								0.38			1.54				0.19							0.51
Gate 4									0.19													0.06
Gate 5																						0.00

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Ultrasonic Testing - computerized system						
Cleanliness Rating System						
Automatic Inclusion Assessment						

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14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Idenfiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

TABLE IX

ULTRASONIC CLEANLINESS RATING

OPEN HEARTH VACUUM DEGASSED COUPON 3A

LATERAL POSITION OF SCAN (INCHES)

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Average of center scans (-0.2" to +0.2")
Gate 1	4.7	1.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7		0.5
Gate 2		3.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.9	0.8	0.8	0.8	0.8	0.7	0.6	0.7	0.7	0.6	2.0		0.8
Gate 3	2.3	3.3	1.0	1.5	1.5	1.5	1.4	2.1	1.8	3.3	10.2	12.1	2.6	1.8	1.5	1.5	1.8	1.2	1.1	1.1	1.2	
	4.1	2.5	1.1	1.6	1.6	1.5	1.3	1.7	2.0	11.2	20.4	3.5	2.2	1.4	1.6	2.2	1.2	1.2	1.0	1.1		
	3.4	1.6	1.3	1.5	1.5	1.5	1.5	1.4	2.1	9.1	37.1	2.4	2.1	1.4	1.4	3.0	1.2	1.1	0.9	1.3		
	4.0	1.1	1.4	1.5	1.6	1.5	2.0	1.6	2.5	8.4	27.0	2.6	2.1	1.4	1.3	2.5	1.3	1.1	0.9	1.1		12.3
Gate 4			0.5	0.6	0.7	0.6	0.7	0.7	0.6	0.7	0.7	0.7	0.7	0.6	0.7	0.6	0.6	0.6	0.6	0.7	0.9	0.7
Gate 5		4.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.5	0.5	0.6	1.5	3.6	0.6

OPEN HEARTH COUPON 2G

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Average of center scans (-0.2" to +0.2")
Gate 1	1.2	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.8		0.6
Gate 2	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.9	0.9	0.9	0.8	0.7	0.7	0.8	0.7	0.6	0.6	0.9		0.9
Gate 3	0.5	0.8	1.6	1.5	2.0	1.8	2.4	1.9	10.6	1669.0	1964.1	1887.0	4.7	2.2	2.7	1.6	2.0	1.3	1.0	16.7	3.2	1338.2
	0.5	1.0	1.6	1.6	2.1	1.7	1.8	2.2	59.8	552.6	2670.7	1411.9	3.0	2.4	2.2	1.6	2.2	1.4	1.1	39.2		
	0.6	1.1	1.7	1.7	2.1	2.4	1.6	3.1	214.0	349.8	2329.7	578.1	2.6	3.1	1.8	1.7	1.8	1.3	4.1	187.4		
	0.7	1.5	1.7	2.0	1.9	2.3	1.8	4.4	1295.4	727.9	1872.9	44.1	2.2	3.2	1.6	1.7	1.4	1.1	75.8	35.8		
Gate 4		1.2	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.8	1.1	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.7	0.9
Gate 5			0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.8	0.6

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13. ABSTRACT

An ultrasonic cleanliness rating system containing high speed data processing facilities was successfully designed, assembled and tested. The system is automatic and can rapidly assess internal cleanliness (non metallic inclusions) of semi-finished material with a high degree of resolution ($6 \times 10^{-6} in^2$). Cleanliness ratings determined by AMS 2301 and the ultrasonic system showed no correlations. However, by modifying the AMS 2301 specification and inspecting a substantially greater number of surfaces, a relationship was established. Inclusion areas as assessed by light microscopy were closely related with inclusion areas measured with the ultrasonic system. Additional studies are recommended.

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TABLE XI

MAGNETIC PARTICLE SEVERITY RATING

LATERAL POSITION OF BILLET INSPECTION (INCHES)

OPEN HEARTH VACUUM DEGASSED COUPON 3A

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Average of center scans (-0.2" to +0.2")
Gate 1								.58	.38		.38	.77	.38	.19		.19		.19				0.38
Gate 2			.96	.38	.96	1.35	1.15				.19	.38			.19	1.35	1.54	.19	.19	.19		0.19
Gate 3			.58	.38	.58						1.35			.19		.38	.19	.58	.38			0.45
Gate 4	.19	.19	1.73	.19	.38		.38		.19								.19	.58	.58			0.00
Gate 5	.96	.38	.38	.19	.38			.38		.19	.19	.19	.38	1.15	.19	.38			.19		.19	0.19

OPEN HEARTH COUPON 2G

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0	Average of center scans (-0.2" to +0.2")
Gate 1															.19							0.00
Gate 2																						0.00
Gate 3					.19												.96					0.00
Gate 4																						0.00
Gate 5		.58																				0.00

AD Accession No.

U. S. Army Materials Research Agency, Watertown, Massachusetts

AN AUTOMATIC COMPUTERIZED ULTRASONIC CLEANLINESS RATING SYSTEM AND CALIBRATION STANDARDS - C. J. Carter, R. A. Cellitti, J. W. Abar International Harvester Co., Mfg. Research, Chicago, Illinois.

Report No. AMRA CR 67-10(F) 30 May, 1967 120 pp · Tables - illus. Contract No. DA-19-066-AMC-314 (x)

D/A Project No. PEMA 15036, AMC Code No. 4930.1

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This report not to be released outside the Government prior to January 1, 1968.

UNCLASSIFIED

1. Ultrasonic testing - computerized system
2. Cleanliness rating system
3. Automatic inclusion assessment

I Carter, C. J.
II PEMA 15036
III AMCMS Code 4930.1

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TABLE XIII

ULTRASONIC SEVERITY RATING OF 1/2 INCH THICK COUPON

SUBSEQUENTLY GROUND & INSPECTED IN 0.005" STEPS

LATERAL POSITION OF SCAN (INCHES)

-1.0	-0.8	-0.6	-0.4	-0.2	Center	+0.2	+0.4	+0.6	+0.8	+1.0
4.3	6.3	9.5	8.5	13.9	9.8	9.7	8.1	12.0	5.7	3.6
4.8	8.2	12.1	10.5	10.3	9.7	10.7	11.4	14.0	4.6	
5.5	9.5	14.8	13.6	8.0	10.9	9.1	11.4	14.0	3.8	
5.3	9.8	10.2	15.5	8.7	10.1	7.3	10.9	7.4	3.4	

MAGNETIC PARTICLE SEVERITY RATING

-1.0	-0.8	-0.6	-0.4	-0.2	Center	+0.2	+0.4	+0.6	+0.8	+1.0
0.017	0.138	0.313	0.390	0.494	0.560	0.520	0.346	0.244	0.144	0.011

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TABLE XV

ULTRASONIC CLEANLINESS RATINGS OF STANDARDS

STANDARD NO. 1

LATERAL POSITION OF SCAN (INCHES)

	-2.0	-1.8	-1.6	-1.4	-1.2	-1.0	-.8	-.6	-.4	-.2	Center	+.2	+.4	+.6	+.8	+1.0	+1.2	+1.4	+1.6	+1.8	+2.0
Gate 1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5				
Gate 2	0.6	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.8	0.7	0.7	0.7	0.9	0.8	0.7	0.7	0.7	1.3			
Gate 3	0.7	0.8	1.2	1.3	1.4	1.6	2.0	2.1	2.8	5.3	5.4	3.3	2.3	2.1	1.9	1.3	1.5	1.5	1.0		
	0.7	0.8	1.0	1.4	1.4	1.6	1.9	2.1	3.5	5.8	4.3	2.9	2.0	1.9	1.8	1.3	1.6	1.4	0.9		
	0.7	1.1	1.1	1.3	1.5	1.8	2.0	2.2	4.6	7.4	5.7	2.2	2.2	2.2	1.7	1.4	1.5	1.2	0.9		
	0.8	1.2	1.2	1.4	1.6	2.1	2.1	2.5	5.1	8.5	5.2	2.5	2.5	2.1	1.6	1.4	1.4	1.2	0.9		
											4.3										
Gate 4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.8	0.6	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.6
Gate 5	0.6	0.5	0.5	0.5	0.5	0.5	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

STANDARD NO. 2

Gate 1	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.6				
Gate 2	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.7	0.6	0.6	0.7	0.6	0.8	0.5	0.6	0.6				
Gate 3	0.5	0.6	0.9	0.9	1.6	1.2	1.2	2.2	2.3	2.2	64.0	7.5	1.5	1.9	1.1	1.1	1.4	2.4	3.2	6.8	
	0.6	0.6	1.0	0.9	1.7	1.4	1.4	2.0	2.3	4.0	108.6	2.6	1.5	1.7	0.9	1.1	1.7	5.5	1.9		
	0.6	0.6	1.0	1.1	1.9	1.7	1.5	2.3	2.2	7.5	29.7	1.8	1.7	1.5	1.0	1.6	1.7	9.4	3.3		
	0.6	0.8	0.9	1.4	1.4	1.4	2.0	2.2	2.1	13.8	11.6	1.6	1.9	1.6	1.1	1.7	1.6	7.6	6.6		
Gate 4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Gate 5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5